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ILLUMINATING ENGINEERING

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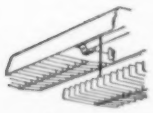
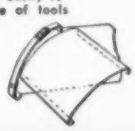


louvers raise or lower on safety chain for ease of maintenance



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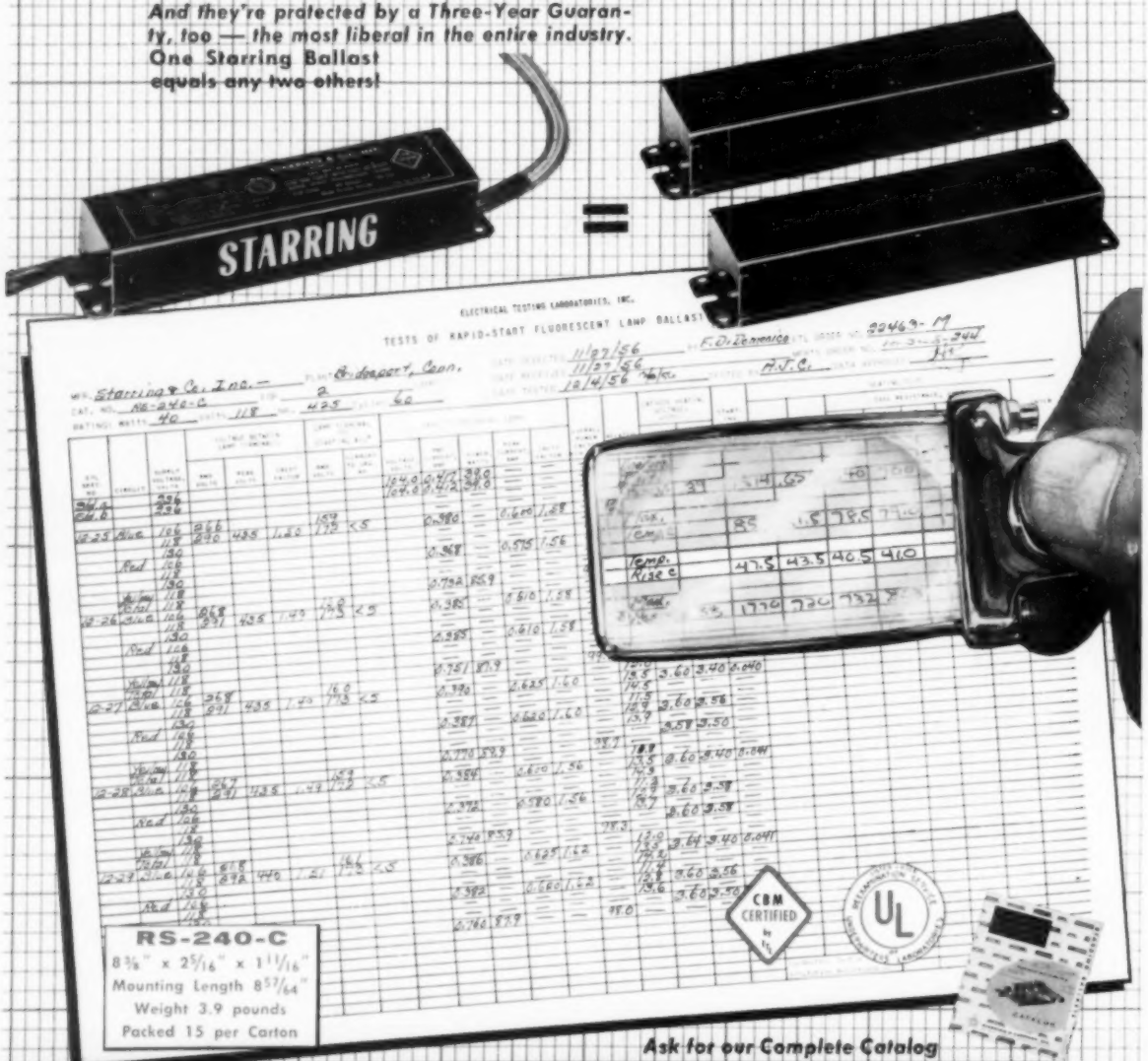

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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

May
1958

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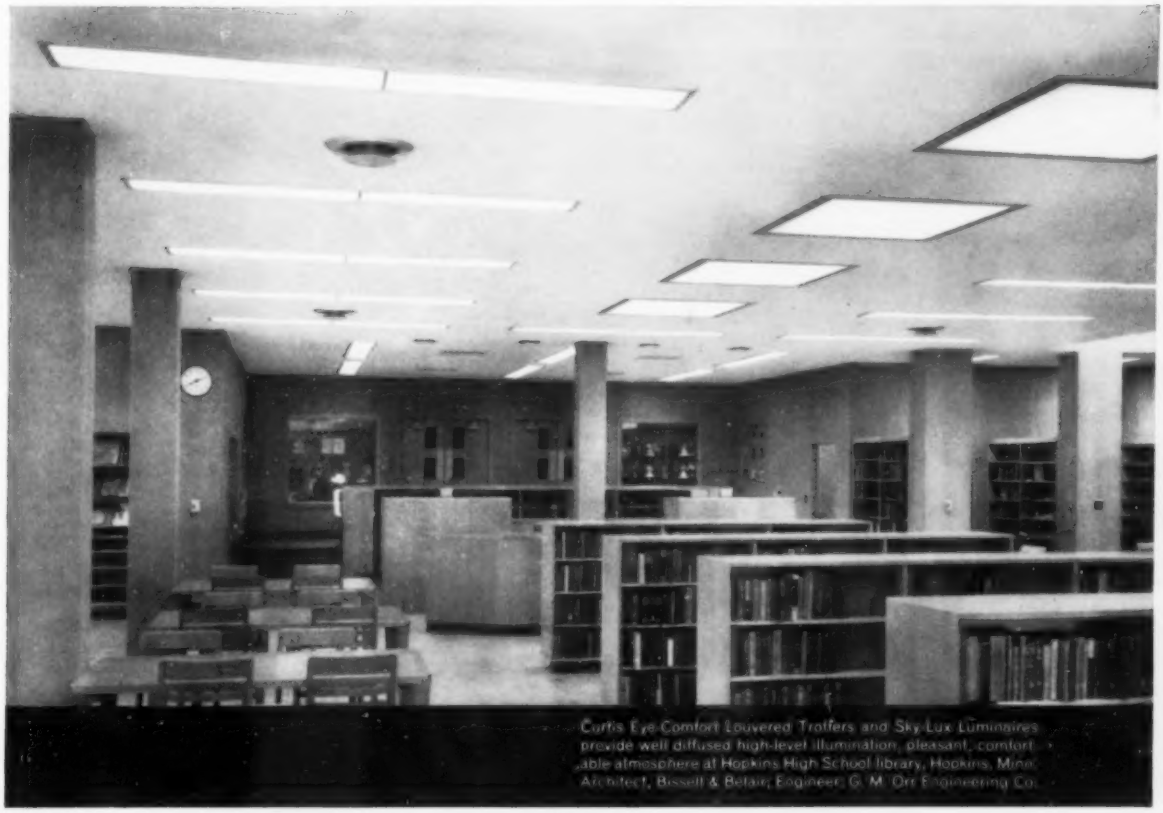
Visioneers...and how they help young minds mature



Curtis Eye-Comfort Louvered Troffers and Sky-Lux Luminaires provide well diffused high-level illumination, pleasant, comfortable atmosphere at Hopkins High School library, Hopkins, Minn. Architect, Bissell & Belair; Engineer, G. M. Orr Engineering Co.

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In the process of learning, young people remember what they *see* much longer than what they hear. Recognizing this fact, school administrators value the importance of providing sufficient light for visual acuity in close classroom work, as well as other activities. Result: an ever-increasing demand for Curtis Planned Lighting Systems. Only natural, because Curtis Visioneers have made detailed and scientific studies of lighting problems inherent to schools. All Curtis school lighting—properly installed—offers uniform level of illumination without objectionable shadows or glare. Curtis Lighting also meets all requirements for *quality illumination . . . low initial cost . . . quick and easy installation . . . minimum maintenance . . . long-run economy*. So, whatever your lighting problem, write today for the name and address of the Curtis Visioneer in the principal city nearest you. Curtis Lighting, Inc., 6135 West 65th St., Chicago 38, Ill. In Canada: 195 Wicksteed Ave., Toronto 17, Canada.

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The same circumstances prevail with this ultra-modern bowling alley. It is an impressive establishment — with sixty continually busy alleys, a modern restaurant and snack bar and air-conditioning. Litecontrol fixtures were chosen to illuminate this handsome interior and to blend into this very well designed structure. They were used throughout except for the area immediately over the alleys.

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BASKETBALL COURTS

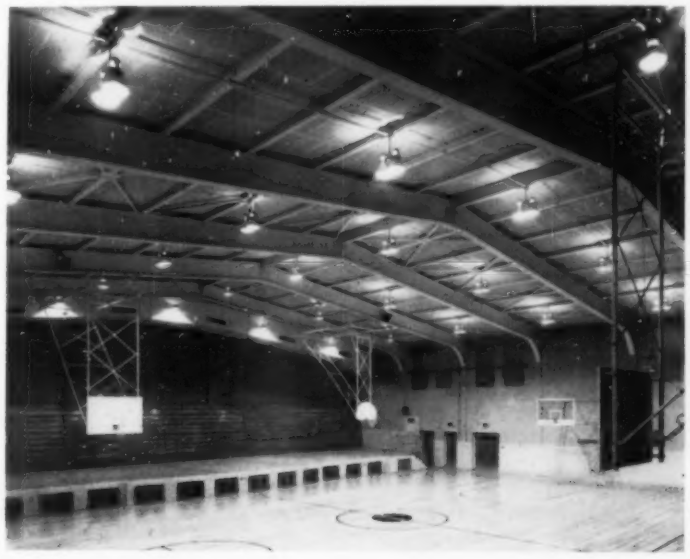
In the section on lighting for basketball courts in the 1952 edition of the *IES Lighting Handbook*, lighting layouts are given only for incandescent filament and 60-cycle fluorescent sources. For today's installations, improved-color mercury, either alone or with incandescent, and the relatively new high-frequency fluorescent are frequently being used, providing over and above the 30 footcandles recommended for high school courts and the 50 for college and professional courts.

• With Incandescent and Improved-Color Mercury

Flexibility in illumination level was one consideration in designing the lighting system for the new gymnasium of St. Ignatius High School. The gym is used for many activities other than basketball — classes, dances, and events sponsored by the Police Athletic League and various local groups.

To provide this flexibility, twin units are used over the playing area, each luminaire having one J-111 improved-color mercury lamp and one 500-watt incandescent lamp. Units have prismatic glass reflectors with upward component. The three levels of illumination available are: 15 footcandles with incandescent only; 30 footcandles with mercury only, and 45 footcandles with the combination. An additional level of 3 footcandles can be provided for dances by using only the incandescent reflector units over the bleacher area. Re-lamping is from the floor with a pole-type lamp changer, through the wire guards on the luminaires.

Architect for the gym, Thomas S. Koehl; contractor, Phillips Electric Co., both of Cleveland. Lighting engineer, Joseph E. Flannery, whose third prize entry it was in the Cleveland Section's 1957 contest for My Most Interesting Lighting Job.



at St. Ignatius High School, Cleveland, Ohio — with all lights on.

milj

at Woodbridge High School, Woodbridge, New Jersey — with bleachers stacked.

• With Improved-Color Mercury

Bleachers extended, ready for use, Tournament court at center.

The gymnasium at Woodbridge High School is 90 by 154 feet in area and includes three complete basketball courts, the center court being for tournament play. For practice, the area is divided into three sections by electrically controlled folding partitions, so that three classes may be held simultaneously. Bleachers, when not needed, stack against the wall, and when in use extend out over the two side courts.

The arrangement of lighting equipment is designed to provide general lighting in the practice courts and localized-general lighting for the tournament court. A total of 72 low-bay prismatic reflector luminaires using 400-watt J-H1 improved-color mercury lamps are installed at a mounting height of 20 feet — 21 units over each side court and 30 over the center tournament court. Units have 45-degree cut-off and 10 per cent upward component. For higher levels over the end zones of the center court, where tournament play is most critical, twin luminaires are used.

Luminaires are hung on cushion-type swivel hangers fastened through conduit fittings to the purlins on the slightly arched roof. Mercury vapor transformers are secured to the purlins adjacent to the luminaires. Stem length of the fixtures varies to compensate for the arch of the ceiling, so that all units are flush with the bottoms of the trusses.

A standby system of eight 1000-watt PS-52 clear incandescent lamps is supplied, with three units over each bleacher area and two over the center court. Exit lights meeting the ordinance requirements provide additional standby lighting.

With partitions closed, illumination readings

were taken after 850 hours operation, using a laboratory calibrated, cosine- and color-corrected light meter. General illumination in side practice courts averaged 50 footcandles. Readings on the tournament court were:

Center jump circle, 53 fc,
Edges of court across from center jump circle, 44 fc,
Foul line, 76 fc,
Edges of court across from foul line, 52 fc,
Under basket, 84 fc,
Foul jump positions near basket, 78 fc,
Edges of court across from basket, 76 fc,
End boundary behind basket, 65 fc,
Corners at side and end boundaries, 76 fc.

Reflection factor of the ceiling is 50 per cent, of walls 50 per cent and of parquet floor 40 per cent. Luminaires are re-lamped from below through the center hole in the ⅛-inch steel bottom guards.

Architect for the installation, Alexander Merchant Associates; consulting engineer, Runyon and Carey Associates. This installation won first prize in the New York Section's 1957 contest for My Most Interesting Lighting Job and placed third at the Northeast Regional contest. It was the entry of Julius Kaye, District Manager and Engineer, New Jersey, Holophane Co., Inc.

• With High-Frequency Fluorescent

A 400-cycle 600-volt fluorescent installation, using fifty 8 x 8-foot luminaires, provided an initial 60-65 footcandles at the Northern Illinois University Field House. Readings were taken at 18 inches from the basketball floor.

Each luminaire has fourteen 8-foot lamps, with individual Alzak reflectors for each lamp. Units are mounted 35 feet above the floor and have 40-degree cutoff. Protection above and below is by 18-gauge steel guards.

The system uses a frequency converter which acts as both a transformer and a frequency changer, and a high-frequency 400-cycle distribution system. Advantages claimed are higher levels at lower cost; smaller and more efficient ballasts, reduction in fixture weight, lower cost for distribution system, and less heat at the fixture, than there would be with a 60-cycle system.

Architect for the fieldhouse, Perkins & Will, Chicago, Ill.; electrical contractor, Berg Electric Co., Rochelle, Ill.; photos and data courtesy the Edwin F. Guth Co., St. Louis, Mo.

at Northern Illinois University Fieldhouse, De Kalb, Illinois — practice time.

Development of
Deluxe Fluorescent-Mercury Lamps
for Commercial and Specialized Applications

By W. S. TILL

THE COLOR characteristics of a light source are clearly recognized to be important in determining its acceptance for most applications. As an example, consider the difference in color rendition between a daylight fluorescent lamp and a deluxe warm white fluorescent lamp, or between daylight and soft white. These represent approximate extremes in creating a cool atmosphere or a warm one from among the family of "white" fluorescent lamps. Even more startling is the difference in color rendition of a mercury lamp and an incandescent bulb, yet both have their applications. Ordinary mercury lamps have a marked deficiency in certain portions of the spectrum, notably in the red section. The golden-white fluorescent-mercury lamp, developed in 1949, provides a marked improvement in color by adding the missing red energy.[1] For many applications, however, a more flattering color balance is desired with a long-life mercury type of lamp. An investigation has therefore been made to determine the possibility of obtaining a "deluxe" color in a fluorescent-mercury lamp, using magnesium fluorogermanate phosphor and an integral filter on the bulb. This paper will describe the test work that has been done and the experimental lamps that have been created.

It is interesting to note that no sooner had Peter Cooper-Hewitt invented the first mercury lamp around 1900 than he set out to improve it.[2] One of the first things he tried was to make a lamp out of quartz rather than glass, and this, of course, gave much higher efficiency but little difference in color. Not long thereafter, Cooper-Hewitt set about to add red to the spectrum of his mercury lamp. He was completely unsuccessful no matter what he tried, but one day he found a dye that fluoresced a brilliant red. Actually, his mother unintentionally helped him discover this. She asked him to turn on his mercury light so some dinner guests could see it. A moment or two later he rushed over with a pair of scissors and cut off about 8 inches from the red-bow sash of her new satin brocade dinner dress, much to her dismay. It was the only article in the room which still looked red under the mercury light. After analyzing the material, Cooper-Hewitt found that it was Rhodamine B dye. Thereafter he used this substance to coat external reflectors which he sold in combination with his lamps. The dye absorbed ultraviolet radiation coming from the lamp and gave off red light, affording some color improvement. But Cooper-Hewitt never discovered a practical means of accomplishing this within the lamp itself.

Those who have studied Cooper-Hewitt's method of obtaining color correction, namely using fluorescent paints on a reflecting surface in combination with a regular mercury lamp, have concluded that it is impractical today because of obvious disadvantages. The overall efficiency is low and the red fluorescing material is subject to deterioration from accumulation of dust and exposure to the atmosphere. Other methods of providing various degrees of color correction with mercury lamps are well known. It has been a fairly common practice to mix filament with mercury lamps where color is important, and detailed studies have been made.[3] The development of the fluorescent-mercury lamp greatly reduced the necessity for intermixing incandescent lamps, except for emergency lighting. Even so, some people have combined the two in order to obtain still better color. Others have used only fluorescent-mercury lamps but have chosen paints for walls and ceiling to blend best with this source.

About three years ago, before the present experimental deluxe fluorescent-mercury lamps were developed, the possibility of improving the color of fluorescent-mercury lighting was investigated along the lines of using standard lamps with either a colored plastic or glass filter as part of the fixture. Fig. 1 shows spectral distribution for a typical fluorescent-mercury lamp. Although the green line has slightly less energy than the adjacent yellow line, it lies closer to the peak of the eye sensitivity curve. Both lines (5461A and 5770-90A) must be cut down somewhat or balanced if a more pleasing overall color is desired. Samples of ⅛-inch thick

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 9-13, 1957, Atlanta, Ga. AUTHOR: Westinghouse Lamp Division, Bloomfield, N. J.

acrylic plastic of several different shades of rose or purple were obtained. It appeared that a very good degree of color modification could be obtained with a loss in total light transmission of approximately 20 per cent; in other words, filter efficiency was 80 per cent. A rose colored sample gave close to a warm white color with yellow and red predominating. A purplish sample gave a cool white appearance with well-balanced overall color but less emphasis to red. Essentially, both samples improved color rendition by reducing the relative amount of green transmitted in the mercury spectrum. One type absorbed blue-green and the other absorbed yellow-green.

Samples of the acrylic plastic were placed where they would be exposed to intense radiation from both mercury and fluorescent-mercury lamps. (See illustration showing life-test facilities.) After approximately 2000 hours exposure, a piece was cut off the sample and returned to the manufacturer for spectral analysis. It was reported subsequently that only a slight change had taken place. Visually the material appeared to be the same as it was originally. Figs. 2 and 3 show curves for these materials, before and after exposure.

The test with acrylic plastic was continued with the original pieces for another 10,000 hours, but without additional spectral analysis. No additional change was apparent visually. Indications are that acrylic of this type will remain approximately the same in color over a period of at least several years' exposure in close proximity to the bulbs; however, limitations of this method of obtaining color improvement are obvious. The fixture must be designed so that all or almost all of the light passes through the plastic. The acrylic must not be overheated. In general, it should not be heated beyond 90 degrees C. Experimental fixtures were made up and tested for two years successfully, except that since the units were open toward the top and closed by the plastic across the bottom and the windows of the room were not screened, the plastic plates soon collected large numbers of deceased bugs and hence became somewhat unsightly. This limitation could be overcome with better designed fixtures or air-conditioning; however, it could also be avoided by using regular fixtures with the new experimental deluxe fluorescent-mercury lamps.

Experiments were also made with glass plates and it was found that a very good color rendition could be obtained by use of a purplish metallic oxide coating. A density of coating sufficient to reduce light output by 20 to 25 per cent was enough to bring about marked color improvement, again by reducing the amount of green transmitted by the mercury type lamp. This type of coating could be used either on glass cover plates of fixtures or on glass reflecting surfaces. (It was not used directly on the bulb because in the meantime a colloidal

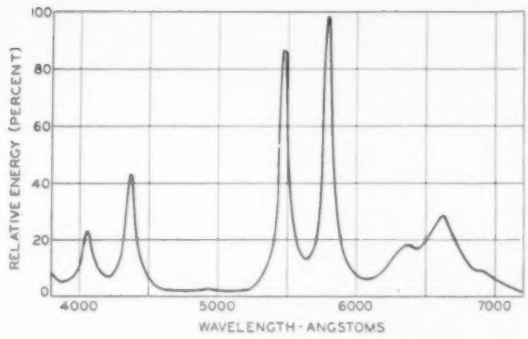


Figure 1. Spectral distribution for a typical fluorescent-mercury lamp (J-H1-WD).

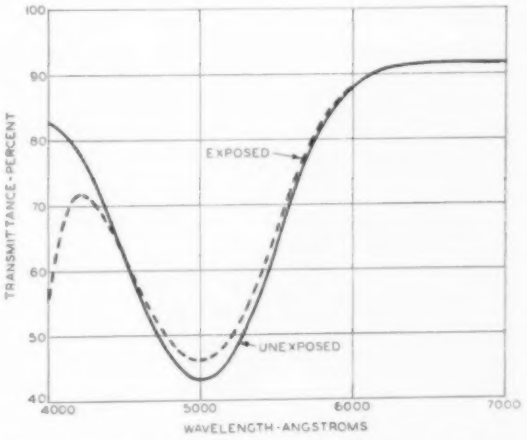


Figure 2. Transmittance of rose colored acrylic plastic before and after exposure to fluorescent-mercury lamps for 2000 hours.

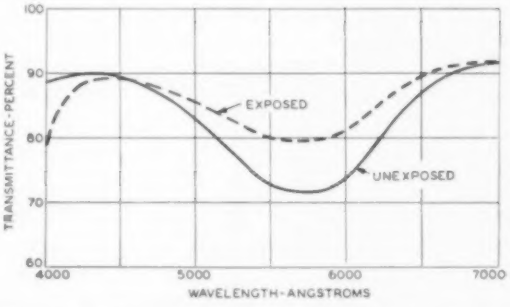


Figure 3. Transmittance of purplish-tinted acrylic plastic before and after exposure to fluorescent-mercury lamps for 2000 hours.

metallic coating, or luster, was found to be more suitable for this purpose.)

The next attempt to improve the color of fluorescent-mercury lamps made with magnesium fluorogermanate phosphor came about with experiments leading to the fixing of a ceramic glaze on the outer bulb surface. It was necessary to clean the bulbs very thoroughly to remove all dirt and lint and to fire the glaze at about 700 degrees C after applying it to the outer bulb, before the latter was made into a lamp. Many different types of color materials were tested. Purple gave an excellent color to the finished lamp, when used with sufficient saturation and hence with considerable reduction in total lumens, but in paler tones the color was judged inadequate, as it did not seem to merit being called "deluxe." We were not able to obtain a satisfactory purple with the ceramic glaze. The most pleasing color was a pale rose shade. It gave noticeably warmer color without too much absorption. The ceramic material acted as a filter, predominantly absorbing green. One important construction detail was noted when the rose glaze was used: it was necessary to have an over-size bulb in order to obtain the most satisfactory color; that it, it was necessary to use a BT-56 instead of a BT-37 bulb when sealing to a 400-watt arc tube. Whenever the ceramic glaze was used with a standard bulb for the particular wattage involved, it was found that the resulting color rendition was too yellow. This came about partly because the rose-colored glaze did not absorb enough yellow and green in proportion to its transmission of red and blue and partly because the thickness or heat transmitting properties of the ceramic material caused the phosphor (magnesium fluorogermanate) to heat up somewhat more than normal, and this tends to make it yellower.[4] It was also found that, with glaze omitted, 400-watt BT-56 bulbs gave slightly better color than 400-watt BT-37 bulbs in fluorescent-mercury lamps of equal coating density. This can be explained on the basis of increased phosphor area and lower temperature. Fig. 4 shows a spectral energy diagram for a 400-watt BT-56 experimental lamp made with the ceramic material. This lamp appears at the extreme upper right of Fig. 5 and was called an M-H1. Because of the necessity of using a very large outer envelope, this early type of so-called "deluxe" fluorescent-mercury type lamp was not found easy to apply, nor particularly economical. It could not be substituted for any existing 400-watt mercury lamp in present fixtures because the light center was completely different and greatly reduced the optical efficiency of the reflector. Such a 400-watt experimental BT-56 lamp could have been used in fixtures designed for 1000-watt mercury lamps, but this was objectionable because of their larger size in the ceiling area as well as greater cost.

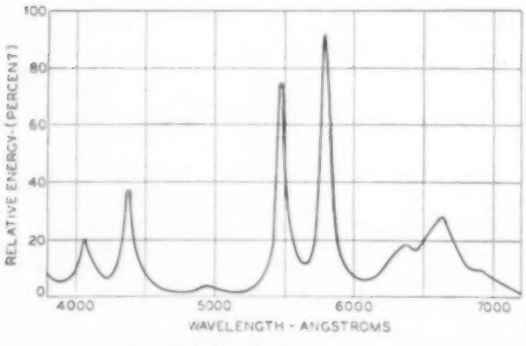


Figure 4. Spectral distribution for first type of deluxe fluorescent-mercury lamp (M-H1), made with rose-colored ceramic glaze. (Note output from 6000-7200A equated to that of Fig. 1 so that relative output at other wavelengths can be compared directly).

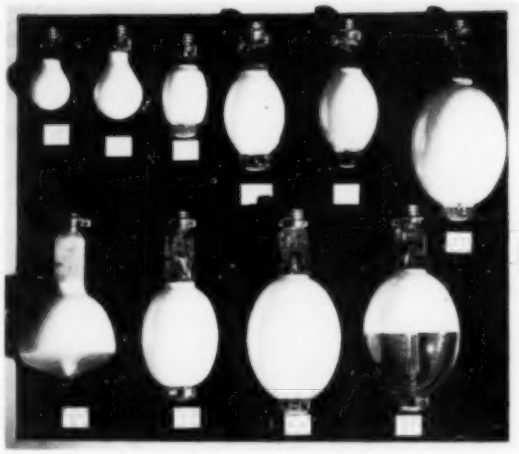


Figure 5. Family of fluorescent-mercury lamps from 100- to 1000-watt size. (Upper right, first type of deluxe fluorescent-mercury lamp, experimental 400-watt M-H1 in oversize envelope, was superseded by deluxe lamps in conventional bulb size).

Recently, deluxe fluorescent-mercury lamps of superior color quality have been developed using a material described as a "purple luster." It is actually a colloidal metallic coating which must be applied to the bulb and fired at high temperature. Tests have shown it to be extremely durable. It will resist most dilute acids. Fig. 6 shows its transmittance characteristics. It can be applied in any desired density to the bulb before it is made into a lamp so that a wide range of color modification is possible. For economical reasons, as well as to

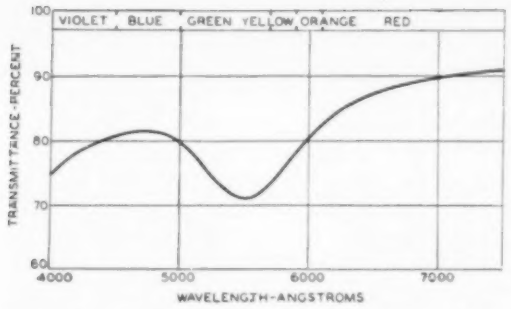


Figure 6. Transmittance of purple luster, colloidal metallic coating, used with present experimental deluxe fluorescent-mercury lamps.

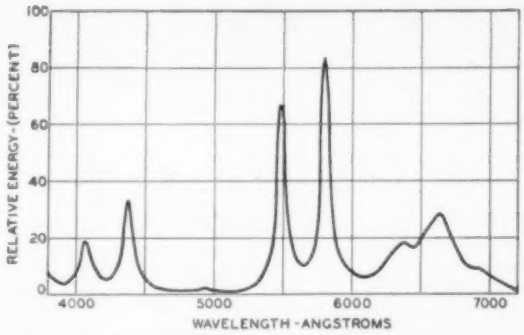


Figure 7. Spectral distribution for typical 400-watt BT-37 bulb experimental deluxe fluorescent-mercury lamp. (Note, output from 6000-7200A equated to that of Fig. 1, to afford comparison of relative output at other wavelengths. Compare also with Fig. 4.)

obtain a reasonably suitable color quality, it has been determined that deluxe fluorescent-mercury lamps, so made, should have a reduction in efficiency of approximately 20 to 25 per cent. It is no longer necessary to use an oversized bulb. The coating causes very little additional heat on the bulb surface, and its color has been chosen to be sufficiently purplish so as to absorb much of the green and so that the yellow tones do not become too evident in the deluxe lamp. The line of deluxe fluorescent-mercury lamps which can be created parallels in every respect that of existing lamps on a comparable wattage basis. Life tests of deluxe lamps, although limited, have been favorable. Fig. 7 shows spectral energy data for a typical lamp of this new experimental family.

Table I lists the lamps which can be made, together with their complete technical data. Fig. 8 shows a photograph of experimental deluxe lamps and their standard counterparts. Fig. 9 shows an outline sketch of a typical lamp, while Table II shows the temperature requirements for the deluxe group. The latter are no different from those already required for standard fluorescent-mercury

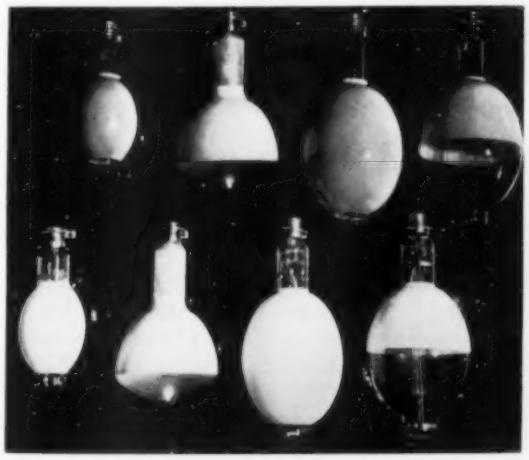


Figure 8. Upper row, group of experimental deluxe fluorescent-mercury lamps: 400-watt BT37, 400-watt R57, 100-watt BT56 and 1000-watt BT56 semi-reflector. Lower row: their standard counterparts: J-H1-WD, P-H1-WD, C-H12-WD (or B-H15-WD) and D-H12-WD (or D-H15-WD).

TABLE I — Technical Data for Experimental Deluxe Fluorescent-Mercury Lamps.

Temporary Designation	J-H1/GWX	*P-H1/GWX	B-H18/GWX	C-H12/GWX	B-H15/GWX	*D-H12/GWX	*D-H15/GWX
Nominal Watts (Lamp only)	400	400	700	1000	1000	1000	1000
Outer Bulb	BT37	R57	BT46	BT56	BT56	BT56	BT56
Outer Bulb Finish		Light Purple Luster, Inside Phosphor Coated					
Approx. Initial Lumens	15,500	15,800	26,300	40,000	40,000	41,500	41,500
Average Useful Life, Hours	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Max. Overall Length, inches	11½	12¾	14½	15⅜	15⅜	15⅜	15⅜
Light Center Length, inches	7	——	9½	9½	9½	9½	9½
Open-circuit Volts, 50° F	220	220	460	220	460	220	460
−20° F	275	275	460	380	460	380	460
Operating Volts (approx.)	135	135	265	135	265	135	265
Starting Current (Amps. approx.)	5	5	5	12	6	12	6
Operating Current (Amps. approx.)	3.2	3.2	2.8	8.2	4	8.2	4

*Semi-reflector lamp. Phosphor-coating applied to reflective portion of bulb directs approximately ⅔ of the light downward through open face of bulb.

NOTE: Lamps listed above all have mogul screw bases and quarts inner arc tubes. Normal warm-up time is 4 minutes, depending on the ballast used. If extinguished, they require four or five minutes to cool down before they will restrike.

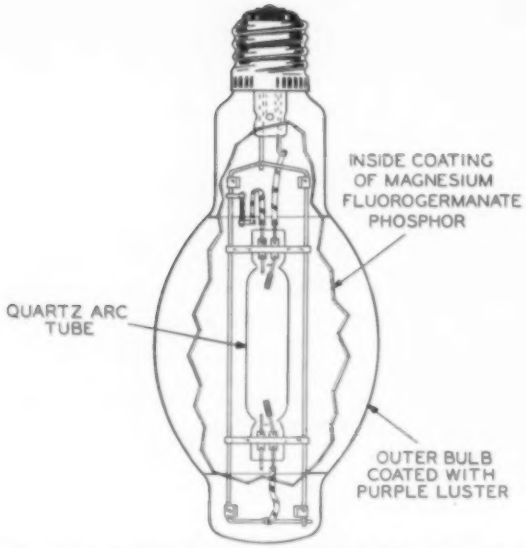


Figure 9. Essential constructional details for typical experimental deluxe fluorescent-mercury lamp.

TABLE II — Luminaire Test Temperature Limits for Experimental Deluxe Fluorescent-Mercury Lamps.

Lamp	Outer Bulb	*Base
400-Watt J-H1/GWX, P-H1/GWX	400° C	210° C
700-Watt B-H18/GWX	400° C	210° C
1000-Watt C-H12/GWX, D-H12/GWX, B-H15/GWX, D-H15/GWX	400° C	210° C

*A 10° C higher test temperature is considered acceptable in outdoor fixtures because the ambient temperatures during operation are generally lower than in other types of service.

NOTE: The above temperatures are not maxima. They are the temperatures which should not be exceeded in a laboratory test, with a new luminaire and a new lamp, operating at rated watts, and an ambient temperature of 25° C. If the lamp bulb and base temperatures do not exceed these values under test conditions, the fixture should be safe in service under all ordinary circumstances.

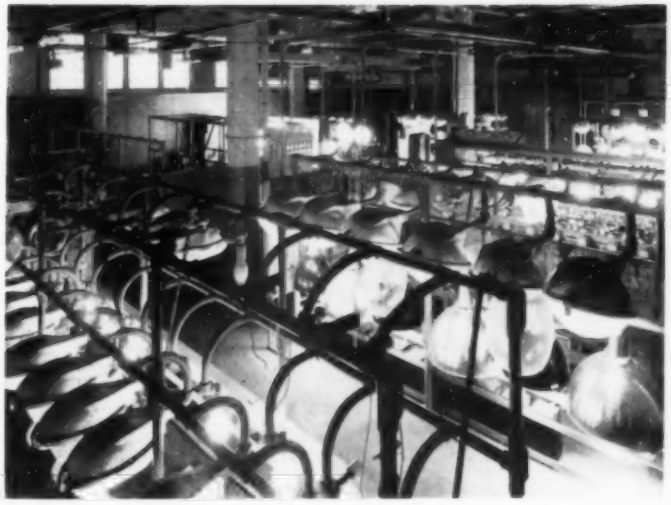
lamps. Other types or shapes of fluorescent-mercury lamps can, of course, be manufactured with the deluxe type of finish, but it seems reasonable that the principal demand will come in the relatively larger sizes. This is because mercury lamps in the 100- and 175-watt class are not as efficient as those of 250 watts and higher.

Magnesium fluorogermanate phosphor is used for the experimental deluxe lamps. The recently-developed orthophosphate silver-white colored phosphor appears to be completely unsuitable for use in a deluxe type of fluorescent-mercury lamp, because it has very much less light in the red spectral regions (6000-7600A) as compared to lamps made with golden white magnesium fluorogermanate. Other phosphors, such as the silicate group, have been analyzed in this connection, but do not show promise. Recently a "daylight" type of phosphor, similar in color to "daylight" fluorescent lamps, has been reported as an experimental development in England, but no data are available. The possibility of achieving a truly deluxe color entirely by means of a phosphor exists, but seems remote at the present time for mercury lamps.

Many applications suggest themselves for the new deluxe fluorescent-mercury lamps. Although regular fluorescent-mercury lamps have been used in a number of installations where color rendition is quite important, as for instance offices, libraries, churches, banks, transportation terminals, basketball gymnasiums, etc., and although some of these are completely successful even without the admixture of any other light source, nevertheless, in certain cases it has been felt that color should be further improved for 100 per cent acceptance. For such installations, the experimental deluxe fluorescent-mercury lamps will be recommended. They will enter any fixtures which will house one of the conventional fluorescent-mercury lamps. A few stand-by filament lamps should be provided where short-duration power failures are frequent and annoying. Mercury lamps, as is well known, require a few minutes to come back on once the power has been interrupted, even momentarily. Wherever they are used, therefore, it may be desirable to provide at least a small amount of incandescent lighting for emergency purposes.

Obviously good brightness control will be necessary as with any other light source. The 400-watt experimental deluxe BT-37 fluorescent-mercury lamp has an average brightness of approximately 65 candles per square inch, as compared with approximately 40 for a 500-watt incandescent lamp in a frosted type of envelope.

Deluxe fluorescent-mercury lamps will be applied first in places that have fairly high mounting height, such as in old offices where the ceiling is perhaps some 15 to 20 feet or more above the working level. One such office in the Georgia Power Co. was lighted with a single 1000-watt C-H12 fluorescent-mercury lamp (see illustration) before the deluxe line of lamps was available.[5] It has been reported that color rendition, as seen in this office, is completely satisfactory. The ceiling and sides of the plenum are painted white, while the walls of the office are of a peach color. Some offices may not be satisfied with the color rendition obtained from a standard fluorescent-mercury lamp, as green is somewhat emphasized. Light green is a popular



Life-test facilities used to expose plastics and glass samples to intense fluorescent-mercury lamp radiation. (The author in the background.) New deluxe lamps are being tested here.

paint for offices since ordinarily it makes people look better by affording contrast, but when the light source itself is predominantly green, there is less contrast.

The advantage of deluxe fluorescent-mercury lamps in office lighting is simply that they afford an opportunity to have economical lighting in large high-ceilinged areas. For a given footcandle level there are fewer fixtures to install and maintain. In old offices where rewiring might be necessary if additional incandescent lamps were to be added, existing outlets can be converted to take deluxe fluorescent-mercury at low cost, with resulting much higher footcandle level. Ballasts can be installed remotely or near the fixtures. Unless the office is exceptionally noisy, care should be taken to see that ballast noise be kept to a minimum. Mercury ballasts can be noisy but most types are fairly quiet, and there is no reason why extremely quiet ballasts cannot be made if they are needed.

A small trial installation of deluxe fluorescent-mercury lamps has been made in an office in Philadelphia. The office space is divided into two major sections separated by the building entranceway. The larger section is lighted by eighteen 400-watt J-H1 fluorescent-mercury lamps each in combination with three 150-watt three-filament lamps. Each group of J-H1 and three-filament lamps is enclosed by a 36-inch hemisphere of acrylic plastic mounted just below the ceiling approximately 18 feet from the floor. The other office area is a large open room containing eight 400-watt fluorescent-mercury lamps in the same combination fixtures.

Experimental 400-watt deluxe fluorescent-mercury lamps in BT-37 outer bulbs were tried out in place of the regular J-H1 lamps in half of the larger office. The incandescent lamps were turned off. It was observed that the resulting color from the deluxe lamps (alone) was as good as that of the combination of J-H1 and incandescent bulbs in the other half of the office. Changing to the deluxe type of bulb without the incandescents lowered the footcandle level by 40 per cent as was expected. This test was merely to find out whether it would be possible to use only a long life mercury type of lamp in place of the combination and still obtain satisfactory color in a critical area. It would appear that this office could be lighted to the same footcandle level by using an experimental 700-watt deluxe fluorescent-mercury lamp instead of the

Actual installation in Georgia Power Company. View of plenum above small office. One 1000-watt C-H12 fluorescent-mercury lamp lights entire office through luminous ceiling shown below the lamp. (Office area not shown; see I.E. for June 1956.)

Center portion of this unusual office is lighted with 400-watt P-H1 semi-reflector fluorescent-mercury lamps. Considerable daylight comes in along back wall.

combination of 400-watt fluorescent-mercury with the filament bulbs. It would be necessary to change the ballast and lower the plastic hemisphere slightly. The advantage would be that fewer replacements would be necessary since the mercury lamps need be changed only once every two or three years, on the average, as against every 1000 hours for the filament lamps.

Another trial installation has been made in a small office in Bloomfield. The office is approximately 10 feet by 12 feet, with a ten-foot ceiling. It contains a window and a desk, some filing cabinets, and generally a private secretary. The original flush ceiling fluorescent lighting was inadequate for secretarial work. An added desk lamp helped but reduced free desk space. A floor lamp of the direct-indirect type was obtained and gave additional light, mostly in a localized area. By changing the floor lamp into a 100 per cent indirect source aimed at the ceiling, using a 400-watt experimental R-57 bulb deluxe fluorescent-mercury lamp burning base down, the desk lamp could be omitted. The modified floor lamp, although not designed to take full advantage of the light source, nevertheless added 23 footcandles on the desk top and quite generally throughout the room, as measured after three months use. The color of the source is satisfactory and does not attract attention when one enters the office, as it blends well with the 40-watt white fluorescent tubes that form the other source of light. This suggests that mercury-type torchieres are worth further investigation.

Store lighting is another possibility for the new deluxe fluorescent-mercury lamps, and it is believed that a very satisfactory overall color rendition can be obtained when these lamps are used alone or carefully mixed with filament or fluorescent lamps, as in a ceiling modular cell. The new deluxe fluorescent-mercury lamps have not yet been tried out in a store. In this connection, however, it is worth noting that one of America's largest chain stores has been testing successfully a few regular 400-watt J-H1 lamps in their Baltimore branch for several years. The J-H1's are mixed in with filament lamps in the toy department in the basement. Conceivably, the new deluxe lamps could light the entire store. In England regular fluorescent-mercury lamps are now being mixed with filament lamps in a number of store window lighting installations. Higher lighting intensities are obtained with less radiated heat and with more attractive color balance.[6] Use of deluxe fluorescent-mercury lamps in this application would seem to offer the possibility of reducing the incandescent load and building up light intensity still further, with excellent color rendition.

Many buildings having high-ceilinged lobbies or hallways could do with much more light than they now have. Substitution of a mercury-type lamp in many cases will give higher footcandle levels and will save money through eliminating some of the labor required frequently to replace the incandescent lamps now mostly used for this purpose.

Bank buildings could, in many cases, utilize light of this source, either as an indirect component as from a massive chandelier or as a direct down light from a high ceiling. The beauty of using deluxe fluorescent-mercury lamps is that it is not necessary to clutter up a ceiling with a tremendous number of fixtures, as would be required in the case of either incandescent or fluorescent lamps. The recent trend toward the use of incandescent down lights stimulates the thought that a mercury-type lamp can also be used in a similar manner with greater overall efficiency and with saving in replacement labor and other operating costs. The semi-reflector lamps should prove most economical.

Deluxe fluorescent-mercury lamps should find a good use in schools. A great many high school and college gymnasiums have been lighted with 400-watt J-H1 fluorescent-mercury lamps in standard types of reflectors. The opinions of many who have seen these is that the lighting is excellent. Certainly it appears fully satisfactory for the sporting

events which are to be held on such floors. When such locations are also used for other affairs, such as dances, or art exhibitions, etc., it is very doubtful that many in the crowd attending such functions notice anything particularly unusual in the lighting. A few persons, however, do have skin of an olive tone which picks up the green rays from standard fluorescent-mercury lamps and gives them an unusual hue. Where this may prove objectionable, the new deluxe fluorescent-mercury lamps offer an excellent opportunity for color improvement, if the difference in light output is given due consideration. It may also be that the new deluxe fluorescent-mercury lamps can be utilized in school corridors or auditoriums when mixed with occasional incandescent lamps to provide against power interruptions.

It was not expected that deluxe fluorescent-mercury lamps would find application in street lighting or in parking lot lighting applications, but some interest has been shown. In general, the color of the light source is not particularly important in such locations, where the average footcandle level is low. Economy is the major factor which makes a mercury or fluorescent-mercury lamp so popular for outdoor use. Generally, lights from store windows and neon signs blend with and improve color in mercury street lighting in downtown areas, and elsewhere people are unlikely to stop to look at themselves, so that even plain mercury lamps are fully acceptable in most cities.

If color is important in a particular street lighting project, as might well be the case where the average footcandle level is to be in the order of 4 or 5 footcandles or more, and if a cost study shows a very considerable advantage to a mercury type source, then the experimental deluxe fluorescent-mercury lamps in the new fixtures may well be chosen for this application. Several cities are now considering them for very important boulevards. It is anticipated that 400-watt, 700-watt and 1000-watt deluxe lamps will be installed soon in test installations.

Tubular fluorescent lamps are, of course, the principal competitor of mercury-type lamps in modern street lighting. One advantage sometimes claimed for them is better color. With low footcandle levels it is doubtful if the claim had much merit, but if it did, then there is now a new champion of the mercury family, namely, the deluxe fluorescent-mercury lamp!

Other likely outdoor applications for deluxe fluorescent-mercury lamps are the lighting of used car lots, filling stations, flower gardens, and promenade areas such as boardwalks along the seashore.

Indoors, it may be expected that museums, libraries, churches, transportation waiting rooms and public areas will find deluxe fluorescent-mercury lamps economical, in addition to stores, offices, banks, schools, etc., which have been mentioned in more detail.

The application of deluxe fluorescent-mercury lamps in industrial applications is not included in the scope of this paper, and the author foresees little need for them in this field. Certainly, much factory lighting needs improvement both quantitatively and qualitatively, but it is believed that this can be accomplished by using previously existing, more economical, mercury or fluorescent-mercury light sources with a greater emphasis on up-lighting. If for any reason the color of golden-white fluorescent-mercury lamps is not quite sufficient, the deluxe types may be used. Cost studies for typical cases indicate that these new lamps will be more economical than filament lamps and than any form of tubular fluorescent lamps yet announced if the mounting height is quite high.

In summary — new experimental deluxe fluorescent-mercury lamps have been created in shapes and sizes corresponding to those of standard lamps of equivalent wattage. Better color rendition is obtained by the use of outer bulbs having a colloidal metallic coating of a light purplish color. Light output is 75 to 80 per cent of that of regular fluorescent-mercury lamps. The deluxe lamps will be found practical and economical for many applications. Trial installations have been and are being made, and it is expected that the new lamps will be available soon for more general testing. Deluxe fluorescent-mercury lamps should open up new markets for mercury-type lamps in commercial and specialized applications.

The author wishes to express his grateful appreciation to H. A. Williams and J. B. Spencer of Rohm & Haas, to A. R. Jaeger of Corning Glass, to W. O. Mascaro of Atlantic Refining Company, and to F. Rokosz and I. Meister of our laboratories.

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DISCUSSION

G. G. Rae:* Modern construction favors low ceiling heights and this, in turn, leads to the extensive use of recessed fluorescent troffers and large luminous area lighting systems for commercial structures. At the same time, we live in a world that is populated very largely with older structures and the majority of our banks, rail terminals, theaters, libraries, museums, and churches were designed and built in a day when majesty and grandeur in the architecture of public buildings was the rule, rather than the exception.

While these structures still fulfill their original architectural functions, they are usually lighted far below modern standards. One solution of the lighting problem is to drop the ceiling or to erect (as in the case of the Pennsylvania Terminal in New York City) partial ceilings supported by posts or cantilevers from the side walls. The lighting is improved by sacrificing the lofty impressiveness that the original designers strove to create.

This paper points the way to the relighting of the vast number of older public buildings now in use in a fashion that will provide adequate levels of illumination with satisfactory color rendition and yet retain the architectural features of such structures.

It is quite evident that further obstacles must be overcome before these new light sources are ready for the market, but certainly the need is present and the skills are available to control the light of these sources properly for maximum utilization of light and visual comfort.

It is the newest of these lamps, the semi-reflector type, that is particularly suited to Gothic style buildings, particularly houses of worship in which relatively lower levels of illumination are acceptable.

In our organization, we have long found that there is no substitute for high output light sources and well-shielded reflectors or prismatic refracting devices for the illumination of high bay industrial areas, sports arenas, or streets and highways. The use of conventional mercury lighting sources originally, and more recently, the improved-color types, has led to the design of many excellent lighting installations in these fields.

The advent of the deluxe mercury fluorescent lamps will extend these applications into the commercial and institutional fields, again making use of appropriate reflecting and refracting equipment.

It is refreshing to realize that light sources are continually being developed so that structures of any size, type and age can be lighted adequately and economically with one of the many light sources available at this time or shortly due out of the laboratory, as these deluxe fluorescent mercury lamps.

W. H. Kahler:** The addition of the deluxe fluorescent-mercury lamp to the presently available colors of clear, silver-white, and golden-white gives the engineer a wide selection from which to choose the best mercury lamp for a particular application. I would like to point out that each of the four available colors has certain color characteristics which can be very useful. This is particularly true in decorative lighting as well as general applications because the combination of mercury lamps with color filters produces some very efficient sources of colored light. Therefore, close collaboration of the illuminating engineer, the architect, and the decorator can result in some very striking decorative effects with these vapor lamp sources which have the fundamental advantages of long life and high efficiency.

Luke Thorington:* The author has well stated the case for a deluxe type of mercury source for applications where color discrimination is important, and I should like to add my congratulations for his fine paper and excellent demonstrations.

I was particularly impressed with the brilliant rendition of the reds and oranges by the incandescent source. While this, of course, would be expected, it was nevertheless most instructive to compare it with so many different sources at the same time, and to observe how it excels in this respect. Since the author has established that a sacrifice in total lumens of up to 25 per cent is acceptable in order to improve color rendition characteristics, it would seem worthwhile to explore the possibilities of combining the incandescent and fluorescent-mercury sources into a single source where the former serves the dual purpose of ballasting the discharge and improving the color rendition.

It is true that such a ballast filament must operate at a rather low temperature (and therefore low efficiency) in order to have a sufficiently long life in this application, but it apparently has not been realized that this is actually an advantage from the standpoint of color rendition. The reason, of course, lies in the fact that the lower temperature radiation (about 2240K compared with about 2854K for an efficient 100-watt tungsten lamp) is a more saturated red, which is highly desirable in the color correction of mercury sources. For example, the combination mentioned by the author of one J-H1 with three (three filament?) 150-watt incandescent lamps (T_c ca. 2854K) has about the same per cent total red radiation as the combination of one J-H1 plus a 350-watt tungsten filament burning at about 2240K. This is evident from Table A showing the per cent energy in the (CIE) eight spectral bands[1] for these two sources. Also included is the tabulation for the J-H1/GWX and it is interesting to note that since the author subjectively equated the rendition of this source with the J-H1/ incandescent combination, it would seem that the tungsten-ballasted J-H1 should also prove acceptable.

With reference to overall luminous efficiency of the deluxe externally ballasted source *vs* that of the self-ballasted combination source, the difference is rather low when one includes the ballast losses of the former. For example, the J-H1/GWX plus ballast would have a net efficiency of about 34 lumens/watt compared to about 30 lumens/watt for the self-contained J-H1 incandescent source.

A third point of no small import, is the fact that the

*Duro-Test Corp., Research Laboratories, North Bergen, N. J.

TABLE A — Spectral Band Data (Per Cent Energy).

Band No.	Spectral Range	J-H1 + (3) 150W Incand.	J-H1 + Tungsten Ballast	J-H1/GWX**
1	380-420	2.65	2.70	3.16
2	420-440	5.26	6.15	7.16
3	440-460	1.09	0.72	0.74
4	460-510	4.38	3.13	3.05
5	510-560	14.56	15.43	15.10
6	560-610	17.90	18.13	18.39
7	610-660	23.06	24.10	26.94
8	660-760	31.05	30.15	25.00

**From data of Buttolph[2] on JH-1 and the author's transmittance of purple luster.

*Holophane Co., Inc., New York, N. Y.
**Westinghouse Electric Corp., Cleveland, Ohio.

external ballast is completely eliminated with the combination source. When it is realized that deluxe type lamps will be used in places where space is at a premium, and quiet operation is a must (offices, etc.) the ballast may become a source of annoyance as the author has indicated. This is in addition to its high initial cost. Elimination of such an item would therefore seem to be a worthy accomplishment.

In view of the obvious advantages of the combination source outlined here, it would seem that it should merit consideration in the applications proposed by the author, and I should like to hear his comments on the matter.

It is worth noting here that combination sources, similar to the type just described, have been manufactured for general lighting use in Europe for 220- to 235-volt applications for some time, and in the United States for 208-volt, 230-volt and 120-volt applications and have met with general acceptance.

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R. R. WYLIE:* This discussion was necessarily prepared before we had an opportunity to view the deluxe fluorescent-mercury vapor lamps or the various materials illuminated by them. We believe that lamps of this type will be very useful where concentrated packages of color energy are required. The principles of the use of subtractive color filtering to obtain a desired energy distribution are of course not new. Mr. Till's paper is another signpost along the way towards the production of a spectrum of high efficiency sources based on high pressure mercury vapor.

However, let the commercial buyer beware, for the light emanating from the high pressure mercury vapor lamp consists of four important lines of energy at 4050, 4360, 5420 and 5780 angstroms. These energy lines contribute heavily to the efficiency of the lamp. In the case of the 400-watt magnesium fluorogermanate phosphor coated lamp (J-H1) the total fluorescent lumens are only about 10 per cent of the total. This is due to the fact that energy is only being added at the red end of the spectrum, where the eye sensitivity is low. There seems to be but small hope that the efficacy of this phosphor can be increased. The development of the strontium zinc phosphate phosphor (400-watt size, S-H1) has brought the total fluorescent lumens to about 30 per cent of the total light generated by the lamp. Fluorescent energy *is present across the entire visible spectrum*, and this produces a highly efficient source. There is much promise that the contribution of this phosphor can be increased with a red component equivalent to or greater than that of the present "J" phosphor. This means more lumens and a decrease in the mercury line-fluorescent band ratio.

It has been our impression that the use of luster coatings to obtain color are difficult to control. The overall per cent transmittance, as well as the individual wavelength transmittance may vary over a considerable range, resulting in varying efficiencies, as well as changing apparent lamp color.

R. D. Churchill:** The author has discussed a very interesting lamp design which is intended to provide good lighting levels with the minimum number of light sources. This is a commendable approach and one in which all of us are interested. The degree to which this is successful depends upon how well this design can measure up to other sources in color rendition and brightness control, as well as in lighting costs.

The percentage red content of this lamp, which the author has chosen to call deluxe, appears to be about 25 to 35 per cent higher than for the present color improved lamps. Although this is certainly a move in the proper direction, we believe most users will still consider color rendition to be poor for commercial applications as compared to cool white or white fluorescent lamps — not to mention the deluxe fluorescent colors.

Mr. Till states that color rendition with this design is about equal to a mixture of the 400-watt improved-color mercury lamp with three 150-watt filament lamps. Experience has shown that present improved-color lamps are equivalent to a mixture of about 30 per cent filament lumens and 70 per cent clear mercury lumens. From this, we would assume that this new lamp is about equal to an equal lumen mixture of filament and clear mercury.

Earlier studies regarding the appearance of complexions under various combinations of mercury and filament lighting were reported in the Allen-Holmes 1948 paper.[1] These studies concluded that an equal mixture of filament and clear mercury lumens resulted in satisfactory appearance for casual seeing conditions such as gymnasium installations. A ratio of about 75 per cent filament and 25 per cent mercury was indicated to achieve good complexion rendition.

The author lists stores as a possible area of application for this lamp. With the attention merchants are directing toward providing the best possible color rendition, such as through the use of deluxe fluorescent lamps, it seems doubtful that a lamp with the rendition characteristics of this design used alone will gain wide acceptance in this field.

Although these lamps do provide a large package of light in a single source, this creates a brightness control problem. Due to the source size, light control will be more difficult, and we expect that for proper shielding luminaire efficiency will be low. Has the author had any experience with commercial fixtures for this lamp?

Our studies have shown that the improved-color J1 and 8-foot high output fluorescent lamps are about equal in overall costs for high mounting height store areas. Due to its lower efficiency, the new design will be higher in overall cost. Recent developments in higher output fluorescent lamps will provide still greater cost differentials with the advantage of good color rendition.

In schools, the primary area of application appears to be in gymnasiums, with some possibility in auditoriums. Although color rendition is probably satisfactory for most gymnasium activities, it is very questionable that it will satisfy all needs, particularly where the gymnasium is a multi-purpose room. With typical school operating conditions, the new lamps appear slightly higher in overall lighting cost than the 8-foot high output lamps. Still higher output lamps, such as power groove, offer additional savings and the opportunity to provide excellent comfort with good rendition.

With regard to gymnasium applications, what has been the author's experience with respect to the stroboscopic effect on fast moving people and objects?

In industrial and street lighting applications, the lower efficiency of this design reduces the margin between mercury and fluorescent lighting costs to the point where many users would prefer the improved comfort, as well as better color rendition of high output or power groove fluorescent sys-

*Sylvania Electric Products, Inc., Salem, Mass.
**General Electric Co., Large Lamp Dept., Cleveland, Ohio.

tems. Also, the lamp restart problem is eliminated with fluorescent systems.

In summary, this new lamp design appears to offer some interesting application possibilities. However, as in all such cases, it is general practice to take into account recent improvements in other light sources. The recent increases in fluorescent lamp output at high efficiency, good color, as well as relatively low brightness will certainly make fluorescent systems the logical choice for a majority of commercial and industrial applications.

Reference

1. Allen, C. J., Holmes, R. E., "Studies in Gymnasium Lighting," ILLUMINATING ENGINEERING, Vol. XLIV, p. 278 (1949).

W. S. TILL:* I wish to thank Messrs. Rae and Kahler for their remarks concerning the many possible applications for the new deluxe white mercury lamps.

Mr. Thorington has presented a calculated tabulation on the color of the J-H1/GWX, or the J-H1-X as it has been called since standardization, compared to combinations of the J-H1 with tungsten lamps and also with tungsten ballast. I am somewhat puzzled as to why the comparison included the J-H1 with tungsten ballast as this theoretical light source would not be the same in color as the self-ballasted lamps that have been described in this country. Visual comparisons of such self-ballasted lamps seem to show that they are stronger in percentage of yellow-green light than the deluxe J-H1-X. The purple luster coating of the latter is effective in minimizing yellow-green transmission, as shown in Fig. 7 of the paper.

Mr. Thorington states that self-ballasted combination lamps approach within a few lumens per watt of the efficiency of our deluxe light source, when the ballast loss of the latter is taken into consideration. I am sure that he meant this claim only for self-ballasted lamps designed for 208 or 230 volts. It does not apply to 120-volt types. Arguments in favor of the deluxe lamps, in addition to their advantage of at least 4 to 5 net lumens per watt and better color for wholly coated types are:

(1) With proper ballasts all deluxe lamps may be operated efficiently from any supply voltage in the 100-500 volt range, whereas self-ballasted lamps must be chosen to match closely the particular voltage that applies, or else the voltage must be regulated to suit the lamps. Thanks to constant wattage or regulated-output ballasts, mercury lamps now are practically unaffected by voltage fluctuation or even by changes occurring over a number of years.

(2) Deluxe white mercury lamps contain no filament wires as do the self-ballasted lamps. This could be a factor toward potentially longer useful life for the deluxe lamps. This takes into consideration the extra blackening given off by the wire itself, and other factors.

My other comments are that self-ballasted lamps may not be found economical on an annual cost of light basis, and a cost analysis should be prepared in each instance. In addition, I would like to point out that deluxe lamps cover a range of sizes from 400 to 1000 watts, rated from 15,500 to 41,000 lumens, whereas self-ballasted lamps presently seem to offer much less variety. Ballast requirements for deluxe lamps were covered in the paper, so I will offer no additional remarks here, other than to point out that there are a number of offices lighted with mercury-type lamps where one cannot hear a bit of noise from the ballasts, even though they are in the same room.

Mr. Wylie suggests that further developments and improved phosphors may permit a line of deluxe fluorescent-mercury lamps which conceivably might have both excellent color rendition and higher output than present types. This is highly desirable. It may prove to be a long-range project. In regard to control of luster density, while there may have been some difficulty in the past, this is no longer a problem due to new techniques that have been developed.

Mr. Churchill has criticized the color characteristics of the deluxe white mercury lamps. The demonstration which accompanied presentation of this paper at Atlanta, showed exactly how various colors look under warm white and cool white fluorescent and also under incandescent lamps, as compared with deluxe white mercury and other mercury colors. I am sure that those who saw this would agree that deluxe white mercury, while different from each other light source, does not have to take a back seat to any. This, however, does not include deluxe fluorescent lamps.

With regard to specific application possibilities, I wonder if the studies made back in the 1940's, before fluorescent-mercury lamps were invented, should be given as much weight now as when first published. The J-H1 and similar non-deluxe lamps have been used very successfully in some critical applications, several of which were mentioned in the paper. It would therefore seem that the deluxe white mercury types would find much greater acceptance than Mr. Churchill's comments would indicate. The Georgia Power Co., for instance, has relighted 6000 square feet of office space in Atlanta using 1000-watt deluxe white C-H12-X mercury lamps, as I mentioned in the paper, and they have found the color acceptable. Regarding stroboscopic effect in gymnasiums, there has been absolutely no difficulty in hundreds of installations. Proper ballasting takes care of this.

I agree with both Mr. Wylie and Mr. Churchill that the improved output of fluorescent lamps, such as various high-output lamps makes them more competitive with mercury than they used to be for various applications. Each case has to be studied on its merits.

The mercury types will have some advantage where it is desirable to keep fixtures smaller, easier to clean, or easier to relamp, as with a bulb changer, and where light must be directed efficiently into useful zones. Many industrial, street and floodlighting installations have these requirements, as do high-ceilinged rooms in general, whether office, store, gymnasiums or public buildings.

*Author.

Deadline for Ballots — May 26

Latest date for receipt of ballots in the election of I.E.S. National and Local Officers, for the years 1958-1959, is May 26, 1958. Ballots should be returned to the General Secretary at the Headquarters Office by that time in order to be counted.

A.I.A. File No. 31

INSTALLATION AT CONNECTICUT LIGHT & POWER CO. OFFICES, NORWALK, CONN.

Lighting a Small Cafeteria

LIGHTING OBJECTIVE: To provide comfortable general illumination in the dining area of a small cafeteria.

GENERAL INFORMATION: The area shown above measures 18 feet by 42 feet and is used as a dining area for workers in an office building. The ceiling height is 9 feet 6 inches. Colors and reflectances are as follows: white ceiling, 78% RF; buff walls, 60% RF; gray floor, 12% RF; red table tops, 8% RF; natural chairs, 15% RF.

INSTALLATION: Eight Fullerton Mfg. Co. catalog No. HO 300 I surface mounted luminaires provide a level of illumination of approximately 18 footcandles after 3000 hours use. Each luminaire is equipped with a 300-watt PS-35 silvered bowl lamp and a Honeylite bottom enclosure. The units are installed individually, on 10-foot centers in 2 rows 9 feet apart.

Brightnesses after approximately 3000 hours use were: luminaire at 45°, 400 fL; ceiling, 4 fL; walls, 5 fL; floor, 2 fL; table tops, 1.5 fL; chairs, 2.5 fL.

Lighting designed by Hill and Harrigan, 909 Whalley Ave., New Haven, Conn., and John Gage, Lighting Engineer, Connecticut Light and Power Co., Norwalk, Conn. Contractor: Bartoli Electric Co., Inc., 22 Knight Street; Architect: Gilroy & Gaydosh, 64 Wall St., Norwalk, Conn.

Lighting data submitted by H. B. Adams, Design Engineer, Fullerton Mfg. Co., Norwalk, Conn. division of Franklin Research Corp., as an illustration of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31

Calculation . . .

of Utilization Coefficients for Indoor Luminaires by Computers

By P. A. ZAPHYR
G. A. HORTON

DIGITAL COMPUTERS have found many applications in the field of illuminating engineering, primarily in the analysis of test data. Earlier papers have described the use of computers for analyzing outdoor asymmetrical luminaire test data.[1,2] In this present paper, a program for computing coefficients of utilization on a work plane for indoor luminaires by the IES approved Zonal Factor Interflectance Method of Jones and Neidhart[3,4,5] is discussed. The main criticism which has been directed at this method is that the calculation procedure is too lengthy. The purpose of this paper is to offer a constructive solution to this problem and also to give the reader a concept of the abilities of computers in processing engineering data.

Summary of the Zonal Factor Interflectance Method

This method considers the ultimate disposition of the flux from every 10-degree annular zone about the luminaire measured upwards from nadir.

The basic candlepower data may be obtained by methods previously described in the literature.[6,7] The standard lumen factors as shown in Table I are used to convert the average candlepower readings to lumens passing through the annular zones.

The flux in each 10-degree zone which strikes the work plane directly *(direct ratio)* is determined from zonal multipliers,[5] and to that is added the flux that reaches the work plane (an imaginary horizontal plane 30 inches above the floor) by interreflection. The ratio of the total flux reaching the work plane to the bare lamp lumens is the *coefficient of utilization*. It is a factor which takes into account the efficiency and distribution of the luminaire, its mounting height, the room proportions and the reflectances of walls, ceiling and floor.

For suspended luminaires the flux which strikes the ceiling directly *(ceiling ratio)* is computed by zonal multipliers in much the same manner as the flux which strikes the work plane directly.

TABLE I — Conversion Factors to Obtain Lumens Through Each Zone from Candlepower at Center of Zone.

Vertical Angles at Center of 10° Zones	Lumen Conversion Factors
5° , 175°	0.095
15° , 165°	0.284
25° , 155°	0.463
35° , 145°	0.628
45° , 135°	0.774
55° , 125°	0.897
65° , 115°	0.993
75° , 105°	1.058
85° , 95°	1.091

The curves provided in the IES approved method[5] are used for obtaining the percentage of downward lumens which reach the work plane after being reflected from the room surfaces. These percentages (called *downward reflected components)* are expressed in curve form as a function of *direct ratio*. These curves can be approximated accurately by parabolas and so can be defined by three points. There is such a curve for each room index, each required combination of surface reflectances, and for each of two possible mountings, ceiling or suspended. For the computer program 400 such curves were used.

For the case of suspended luminaires, the percentage of upward lumens which reaches the work plane is expressed as a straight-line function of the *ceiling ratio*. These percentages are termed *upward utilization factors*. For ceiling mounted luminaires the *ceiling ratio* does vary substantially, so the *upward utilization factors* may be tabulated. There are 200 *upward utilization factor* curves and tabular values, one for each of the various combinations of room indices and surface reflectances.

Having obtained the *direct ratio*, *downward reflected component*, and *upward utilization factor*, the total percentage of bare lamp lumens reaching

AUTHORS: Westinghouse Electric Corp., Analytical Dept., East Pittsburgh, Pa., and Lighting Division, Cleveland, Ohio, respectively.

the working plane is readily computed. The reader interested in obtaining a more detailed explanation of the Zonal Factor Interflectance Method is referred to the papers by Jones and Neidhart.[3,4]

While relatively few computations and references to curves are required for computing only *one* coefficient of utilization, as many as 200 coefficients might possibly be required to cover many possible situations as to room indices, room surface reflectances, etc. Since this represents many hours of manual labor, it was natural to consider programming these computations for a digital computer.

The important point to be stressed here is that 2428 data items are required to specify the necessary curves and tables for computer processing. Appendix I contains a description of these data. We shall next show how the computer is set up to perform the calculations.

Computer Program for the Zonal Method

A computer program is that set of instructions which directs the computer to perform a specified sequence of numerical calculations and simple "either/or" logical choices. Most modern computers contain the program, as well as the numerical data, in their various storage devices, permitting the selection of alternate sequences of instructions to be executed depending on the outcome of a logical choice. The ability to perform arithmetical operations at high speeds* coupled with the flexibility of logical choices, and the capacity to store large quantities of data, permits one to prepare computer programs for the most complicated computational methods. Once the program has been written and tested, the computer can be relied upon to give accurate results with little human effort for case after case.

The Zonal Method is characterized by the large quantity of data required to obtain the utilization coefficients, as displayed in Appendix I. In deciding how to represent these data in the computer, one may consider the possibility of generating them from formulas. However, to do so requires additional computing time over the time required to refer to data items stored internally. Thus, if the computer selected has sufficient storage capacity it is more economical to store all of these data items rather than compute them as required.

Since the computer most available for our use was the IBM Type 704,[8] which has magnetic drum capacity of 8192 words (one word is a 10 decimal digit number) as well as magnetic core capacity of 4096 words, it was decided to store all 2428 data items. The plan was to maintain the data on magnetic drums and the program instructions in the magnetic cores. Since the computer operates on data stored in magnetic cores only, the data must be transferred from drums into the cores as needed.

The computer program is step-for-step the same procedure one would follow in performing the calculations manually. The photometer readings are converted to candlepowers and then to zonal lumens. From these, the direct and ceiling ratios are obtained for each of the ten room indices and for the pre-specified spacing-to-mounting-height ratio. With reference to the stored curves of upward and downward reflected components, the coefficients of utilization are computed for each of the 200 combinations of room indices and surface reflectances for the given type of mounting, ceiling or suspended. A second degree interpolation formula is employed to refer to the parabolic curves of downward reflected components.[9] Provision is made to eliminate unnecessary computations in the case of totally direct and totally indirect luminaires by skipping those portions of the program that do not apply. The results are then tabulated in report form.

Fig. 1 contains the printed results for a suspended fluorescent luminaire, with spacing-to-mounting-height ratio of 0.4. There are two lamps, of 6800 rated lumens each, in the luminaire. For each of six annular zones, identified by vertical angles measured upward from the nadir, the lumens, per cent of bare lamp lumens and per cent of luminaire lumens, are printed. The candlepower values corresponding to every photometric reading are next tabulated. Readings are taken at the centers of the ten-degree lateral zones for the three horizontal positions, 0, 45 and 90 degrees. Average candlepower and average lumens are tabulated for each zone assuming symmetry from 0 to 360 degrees horizontal. Finally, the utilization coefficients for the 200 combinations of room indices and surface reflectances considered are printed and labeled as shown in the bottom half of Fig. 1. For example, the utilization coefficient for room Type E with 30 per cent floor, 70 per cent ceiling and 30 per cent wall reflectances is 0.605.

About ten minutes are required to key punch the photometer readings and other data describing the test case; less than two minutes are required to read the program cards containing the instructions, tables and curve data into the computer; and less than one-half of one minute is required to perform the calculations and print the results for each test case. After the computer completes the processing of one test case, the next test case is run into the

*For example, addition of two ten-digit numbers can be performed in times ranging from .00025 second for the smaller commercially available digital computers, to .000024 second for the larger ones.

LUMINAIRE TEST NO. K 598620.

BARE LAMP LUMENS 6800. LAMPS IN LUMINAIRE 2.

ZONAL DEGREES	0-30	0-40	0-60	0-90	90-180	0-180
ZONAL LUMENS	2391.	3983.	7437.	9612.	2341.	11953.
PERCENT LAMP LUMENS	17.58	29.28	54.68	70.67	17.22	87.89
PERCENT LUMINAIRE LUMENS	20.01	33.32	62.22	80.41	19.59	100.00

VERTICAL ANGLE	5	15	25	35	45	55	65	75	85
0 DEG. HORT. CP	2984.	2897.	2691.	2405.	2043.	1620.	1090.	586.	118.
45 DEG. HORT. CP	2978.	2922.	2779.	2561.	2274.	1994.	1420.	797.	156.
90 DEG. HORT. CP	2947.	2916.	2822.	2610.	2480.	1969.	1339.	505.	143.
AVE.CANDLE POWER	2972.	2914.	2768.	2534.	2268.	1894.	1318.	671.	143.
AVERAGE LUMENS	282.	828.	1281.	1591.	1755.	1699.	1308.	710.	156.

VERTICAL ANGLE	95	105	115	125	135	145	155	165	175
0 DEG. HORT. CP	44.	174.	343.	530.	698.	835.	959.	1034.	1065.
45 DEG. HORT. CP	106.	131.	190.	321.	458.	592.	729.	941.	1047.
90 DEG. HORT. CP	118.	249.	156.	268.	405.	542.	679.	835.	1059.
AVE.CANDLE POWER	93.	171.	220.	360.	505.	640.	774.	938.	1054.
AVERAGE LUMENS	102.	181.	218.	323.	391.	402.	358.	266.	100.

10* FLOOR CEIL.	WALL	ROOM TYPE J	I	H	G	F	E	D	C	B	A
80*	50*	0.291	0.380	0.453	0.525	0.579	0.649	0.698	0.730	0.774	0.807
	30*	0.237	0.322	0.392	0.463	0.516	0.592	0.643	0.683	0.734	0.771
	10*	0.204	0.283	0.350	0.419	0.472	0.546	0.600	0.641	0.697	0.739
70*	50*	0.285	0.373	0.443	0.514	0.564	0.633	0.676	0.709	0.751	0.780
	30*	0.235	0.319	0.387	0.456	0.507	0.579	0.628	0.665	0.714	0.751
	10*	0.203	0.280	0.346	0.413	0.464	0.537	0.588	0.628	0.681	0.722
50*	50*	0.276	0.357	0.424	0.488	0.537	0.599	0.640	0.670	0.707	0.735
	30*	0.231	0.311	0.375	0.440	0.487	0.554	0.599	0.632	0.677	0.709
	10*	0.198	0.275	0.338	0.402	0.451	0.517	0.567	0.602	0.651	0.687
30*	30*	0.228	0.303	0.363	0.424	0.468	0.529	0.570	0.600	0.639	0.669
	10*	0.196	0.270	0.330	0.391	0.436	0.500	0.543	0.575	0.619	0.653

30* FLOOR

80*	50*	0.295	0.390	0.470	0.550	0.612	0.700	0.759	0.804	0.866	0.912
	30*	0.241	0.328	0.399	0.477	0.536	0.623	0.686	0.735	0.811	0.863
	10*	0.206	0.285	0.353	0.425	0.481	0.565	0.629	0.681	0.753	0.815
70*	50*	0.290	0.383	0.458	0.534	0.594	0.675	0.732	0.773	0.830	0.870
	30*	0.239	0.324	0.394	0.466	0.523	0.605	0.666	0.711	0.774	0.823
	10*	0.203	0.282	0.349	0.419	0.474	0.554	0.613	0.660	0.728	0.782
50*	50*	0.281	0.366	0.436	0.505	0.558	0.628	0.677	0.709	0.759	0.798
	30*	0.233	0.315	0.381	0.450	0.500	0.573	0.630	0.664	0.717	0.759
	10*	0.200	0.276	0.340	0.407	0.456	0.531	0.584	0.625	0.683	0.727

* PER CENT REFLECTIVITY

Figure 1. Printed results for a suspended fluorescent luminaire with spacing-to-mounting-height ratio of 0.4.

computer and processed without reloading the program cards. The process repeats itself until all test cases to be run have been completed.

Automatic Programming Techniques

It is significant that the time and effort required to prepare this computer program have been substantially reduced over earlier experiences by the recent availability of automatic programming techniques. These techniques permit one to construct a computer program by writing the instructions in a form very closely resembling algebraic equations.

Use of automatic programming techniques often reduces the amount of writing required by the programmer by one-tenth and eliminates most of the tedious clerical work associated with constructing and testing the program.

These aids to programming, commonly called compilers, take the form of a computer program which processes condensed mathematical and logical statements to form an equivalent set of computer instructions. The most popular compiler for the IBM Type 704 computer is called FORTRAN,[10] short for formula translation. To illustrate, consider the equation for determining the *downward reflected component*, Y, from the computed *direct ratio*, X, based on Lagrange's interpolation formula[9] on the three points

$$(X1,\ Y1),\quad (X2,\ Y2),\quad (X3,\ Y3)$$

representing the curve. The FORTRAN statement is written and punched into cards in the following form:

```
Y = Y1*(X-X2)*(X-X3) / [(X1-X2)*(X1-X3)]
  + Y2*(X-X1)*(X-X3) / [(X2-X1)*(X2-X3)]
  + Y3*(X-X1)*(X-X2) / [(X3-X1)*(X3-X2)]
```

With an asterisk used to represent multiplication, the algebraic meaning of the above equation is clear. This statement is automatically translated by FORTRAN into 33 coded instructions, a typical instruction taking the form —

```
+0 2400 0 01543.
```

When the coded instructions are executed by the computer, the downward reflected component Y is computed for any direct ratio X provided the proper curve has been referred to for the room index and surface reflectances being considered. It is estimated that FORTRAN reduced the total elapsed time for preparing the program of the Zonal Method by fifty per cent.

Conclusions

We have found that the computer processing of the Zonal Method is highly satisfactory from the standpoint of processing time, costs, reliability of results, and initial efforts to prepare the program. As the power of the digital computer for engineering applications becomes more widely recognized and the availability of these computers becomes greater, we shall find many applications in the field of illuminating engineering, primarily in the reduction of test data.

Today, it is possible for most lighting test laboratories to economically justify the use of digital computers. Small computers are available which can process calculations such as the Zonal Method in relatively short times. For those who do not wish to purchase or rent a computer, service organizations are in existence which will assume the responsibility of programming and processing test data on their own computers. Those who take advantage of this new tool will find, as we have, that computers can be of great assistance to a lighting test laboratory.

Employing digital computers offers a further advantage. It removes the requirement of keeping the computations simple for a method to be considered practical. Thus, it becomes possible to put into practice more sophisticated techniques and thereby gain the increased accuracy they provide.

Acknowledgments

The authors wish to acknowledge the work of Mr. R. S. Coates of the University of Pittsburgh who prepared and tested the FORTRAN program of the Zonal Method while employed with our company in the summer of 1957. Also the assistance of Mr. Ronald A. Gabel in developing the program is appreciated.

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(See Appendix I on following page)

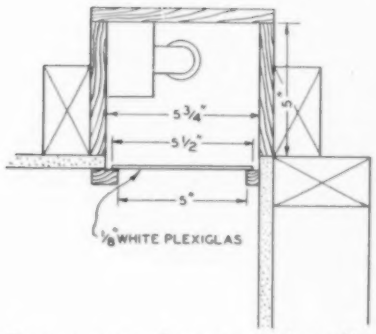
Appendix I — List of Tabular Data Stored on 704 Magnetic Drums

Description of Data	Number of Items
1. Curves for *downward reflected components* for *ceiling mounted* luminaires. There are 200 such curves each represented by three points, giving the downward reflected component as a function of direct ratio for 200 out of the possible 240 combinations* of: (a) 10 per cent and 30 per cent floor reflectances, (b) 30 per cent, 50 per cent, 70 per cent and 80 per cent ceiling reflectances, (c) 10 per cent, 30 per cent and 50 per cent wall reflectances, (d) ten room types. The direct ratios corresponding to the three points on each curve are not in this table since they remain unchanged by room type. (See Fig. 1a of Reference 5.)	600
2. Curves for *downward reflected components* for *suspension mounted* luminaires. These take the same form as data in the above paragraph. (See Fig. 2a of Reference 5.)	600
3. Table for *upward utilization factors for ceiling mounted* luminaires, one entry for each of the 200 combinations of floor, ceiling and wall reflectances and room types considered. (See Table I of Reference 5.)	200
4. Curves for *upward utilization factors* for *suspended* luminaires expressed as functions of ceiling ratios. There are 200 such curves, one for each of the 200 combinations of reflectances and room types considered. Each curve is a straight line and is represented by two points for ceiling ratios of 0 and 1. (See Fig. 3a of Reference 5.)	400
5. *Zonal multipliers* for computing *direct ratios* for spacing-to-mounting-height ratios of 1.0, 0.9, 0.8, 0.7, 0.6 and 0.4 and for the ten room types and the nine 10-degree zones from 0 to 90 degrees. (Work sheets IIa, IIb, IIc, IId, IIe and IIf of Reference 5.)	540
6. *Zonal multipliers* for computing *ceiling ratios* for the zones 90 degrees to 180 degrees and the ten room types. Zones 160 degrees to 170 degrees and 170 degrees to 180 degrees have multipliers of 1.0 and are not listed. (See work sheet III of Reference 5.)	70
7. Conversion factors to obtain lumens through each 10-degree zone from 0 degrees to 180 degrees from the candlepower at center of each zone. (See Table I of this paper.)	18
Total — 2428 data items.	

*See Fig. 1 for those combinations which are employed.

TOLERANCES down to .0001" are encountered in work done in this machine shop, at Zamco Engineering Co., Venice, Calif. Levels averaging 120 footcandles, after three months operation, are obtained from the slotted industrial reflectors and standard cool white lamps on 800 ma. Continuous rows on 8-foot centers are mounted 12 feet from the floor. Ceiling height ranges from 13 to 20 feet. Ceiling has been sprayed with mill white; walls are white and light green; floor is light cement. Brightness contrasts (except for lamps and reflectors) range within a one to five ratio.

Electrical Contractor: Atomic Electric; Illuminating Consultant: Harold I. Strahn, Department of Water and Power, City of Los Angeles.



Cross section of custom-built troffer.

INSTALLATION A IN DALLAS, TEXAS.

Wall Lighting for Hallways

LIGHTING OBJECTIVE: To illuminate narrow interior passageways in a distinctive manner without taking valuable wall space.

GENERAL INFORMATION: Shown above is a hallway 7 feet wide (including stairwell) and 19 feet 4 inches long, with an 8-foot ceiling. The ceiling is flat white (87% RF), the floor is green slate (35% RF) and the walls are paneled in cherry (10% RF).

INSTALLATION: The troffer on the right side of this hallway gives the desired effect of a cornice. In such a long and narrow area the designer felt that the troffer would be less clumsy. In the troffer is a single continuous row of four 40-watt and one 20-watt deluxe warm white fluorescent lamps.

Three Gotham No. 501SP wall brackets, each with two 60-watt lamps, are mounted on the stairwell wall.

With all the lighting turned on, the average illumination in this hallway is 20 footcandles,

(over)

A.I.A. File No. 31

Installation B: Hallway with similar troffer except that bottom shielding is of cast plastic louver panels. This bedroom corridor is 3 feet 3 inches wide and 16 feet 3 inches long. Ceiling and left wall are green grass cloth (45% RF), the right wall is pink (60% RF), and the carpet is beige (65% RF).

with 16 footcandles average 30 inches above each step. Brightnesses from camera position are as follows:

Ceiling		Right wall	
Above left wall	38 fL	One foot below luminaire	5.8 fL
Center	2 fL	Center	0.6 fL
Luminaire (troffer)	490 fL	Door	13.7 fL
		Floor	3.8 fL

Credits: Installation A: Hal M. Moseley, architect and William Blessing, builder; Installation B: Ray Blanchard, designer and builder.

Lighting data submitted by Ruth Patterson, Dallas Power and Light Co., Dallas, Texas as an illustration of good lighting practice and to aid in the design of similar installations.

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Approximations and the Interflection Method

By DOMINA EBERLE SPENCER

For several years, every I.E.S. Conference has included one or more papers on the accuracy of the interflection method. The excellent experimental investigation of Churchill and Putnam[1] is in exceedingly good agreement with the interflection tables. The accuracy of the experimental techniques of Bull[2] and Wiseman,[3] on the other hand, has been seriously questioned.

When experimental investigations are compared with the calculated results of the interflection method,[4] it is impossible to identify the source of the discrepancies. These may be produced by

(1) Inherent characteristics of the interflection method:
   (a) use of approximate exponential kernels,
   (b) assumption of wall uniformity at any level.
(2) Characteristics of model room:
   (a) imperfect diffusion of room surfaces,
   (b) selective or chromatic room surfaces,
   (c) lack of uniformity of self-luminous surfaces,
   (d) obstructions in room such as furniture, people, or measuring equipment.
(3) Experimental technique:
   (a) incorrect measurement of light incident on photocells at large angles,
   (b) inaccurate calibration of instruments,
   (c) variations of voltage, temperature, etc.

Previous discussions have speculated on the source of the discrepancies, but it has hitherto been impossible to separate those which are the result of the use of the approximate kernels from those which arise from characteristics of the model rooms and are purely experimental in nature.

The purpose of this paper is to present a summary of a method[5] by which an exact solution of the integral equation can be obtained, free from the effects of the approximate kernels. Thus, the actual discrepancies produced by the use of exponential kernels can be calculated and item 1a can be separated from the remaining sources of possible discrepancy.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 9-13, 1957, Atlanta, Ga. AUTHOR: Associate Professor, University of Connecticut, Storrs, Conn., Consultant, Marlux Corp. Accepted by the Papers Committees as a Transaction of the I.E.S.

The exact and approximate solutions will be analyzed for ceiling lighting in the extreme cases of very low and very high reflectances. Conclusions will be drawn on the accuracy of the present interflection tables and the advisability of employing corrections.

Exact and Approximate Solutions

A previous paper[5] developed a method of evaluating the errors associated with the use of approximate kernels. The procedure starts with the exact integral equation and the approximate solution. From these, a new integral equation is developed in which the unknown is the discrepancy between exact and approximate solutions. Since the auxiliary equation deals with magnitudes that are only a few per cent of the original quantities, a crude numerical solution of the auxiliary equation is satisfactory.

In this section, the method will be applied to the interflection problem in rooms with ceiling lighting. In the notation of previous interflection papers,[4] the integral equation is written

$$H_1(s) = \rho_1 \left[A(s) H_{02} + \int_0^{h/w} K_{11}(s,t) H_1(t)\, dt \right. \quad (1)$$
$$+ \rho_2 A(s) \int_0^{h/w} K_{12}(t) H_1(t)\, dt$$
$$\left. + \rho_3 B(s) \int_0^{h/w} K_{13}(t) H_1(t)\, dt \right].$$

where

$$A(s) = \frac{K_{21}(s) + \rho_3 K_{23} K_{31}(s)}{1 - \rho_2 \rho_3 K_{32} K_{23}},$$

$$B(s) = \frac{K_{31}(s) + \rho_2 K_{32} K_{21}(s)}{1 - \rho_2 \rho_3 K_{32} K_{23}}.$$

Using the subscript a to denote the approximate solution employed previously,[4] we let

$$\begin{aligned} H_1(s) &= H_{1a}(s) + \delta_1(s), \\ K_{11}(s,t) &= K_{11a}(s,t) + \Delta_{11}(s,t), \\ K_{12}(t) &= K_{12a}(t) + \Delta_{12}(t), \\ K_{13}(t) &= K_{13a}(t) + \Delta_{13}(t), \\ A(s) &= A_a(s) + \xi(s), \\ B(s) &= B_a(s) + \eta_1(s). \end{aligned} \quad (2)$$

As $H_{1a}(s)$ is the solution of Eq. (1) when exponential approximations of the kernels are employed, it must satisfy the integral equation,

$$H_{1a}(s)=\rho_1\left[A_a(s)H_{02}+\int_0^{h/w}K_{11a}(s,t)H_{1a}(t)\,dt+\rho_2 A_a(s)\int_0^{h/w}K_{12a}(t)H_{1a}(t)\,dt+\rho_3 B_a(s)\int_0^{h/w}K_{13a}(t)H_{1a}(t)\,dt\right]. \quad (3)$$

Subtracting Eq. (3) from Eq. (1),

$$\mathfrak{d}_1(s)=f(s)+\rho_1\int_0^{h/w}K_{11}(s,t)\mathfrak{d}_1(t)\,dt+\rho_1\rho_2 A(s)\int_0^{h/w}K_{12}(t)\mathfrak{d}_1(t)\,dt+\rho_1\rho_3 B(s)\int_0^{h/w}K_{13}(t)\mathfrak{d}_1(t)\,dt, \quad (4)$$

where

$$f(s)=\rho_1\left[\xi(s)H_{02}+\int_0^{h/w}\Delta_{11}(s,t)H_{1a}(t)\,dt+\rho_2 A(s)\int_0^{h/w}\Delta_{12}(t)H_{1a}(t)\,dt+\rho_2\xi(s)\int_0^{h/w}K_{12a}(t)H_{1a}(t)\,dt+\rho_3 B(s)\int_0^{h/w}\Delta_{13}(t)H_{1a}(t)\,dt+\rho_3\tau_i(s)\int_0^{h/w}K_{13a}(t)H_{1a}(t)\,dt\right].$$

The chief problem is to determine the approximate solution of Eq. (4) and thus to evaluate $H_1(s)$, the *exact* solution. Once this has been completed, the remaining interflection tables can be computed from the following relations:

$$H_2=\frac{H_{02}+\rho_2\int_0^{h/w}K_{12}(t)H_1(t)\,dt+\rho_2\rho_3K_{32}\int_0^{h/w}K_{13}(t)H_1(t)\,dt}{1-\rho_2\rho_3K_{32}K_{23}}, \quad (5)$$

$$H_3=\frac{\rho_3K_{23}H_{02}+\rho_3\int_0^{h/w}K_{13}(t)H_1(t)\,dt+\rho_2\rho_3K_{23}\int_0^{h/w}K_{12}(t)H_1(t)\,dt}{1-\rho_2\rho_3K_{32}K_{23}}, \quad (6)$$

$$f_2(h')=\int_0^{h'/w}K_{1w}(t)\frac{H_1(t)}{H_{02}}\,dt+K_{2w}\frac{H_2}{H_{02}}. \quad (7)$$

Rooms with Low Reflectances

As a preliminary to the application of the foregoing method, let us consider the relatively simple case of a room with black walls and floor. This is not the type of room for which the interflection method was designed, nor would it satisfy any conceivable standards for quality in lighting. Nevertheless, the interflection equations may be applied to such a room. The results are interesting for two reasons:

(a) Discrepancies between exact and approximate solutions can be expected to be maximum.

(b) Since there are no interflections, exact expressions can be obtained easily without solving an integral equation.

Consider ceiling lighting in a black room with $\rho_1=\rho_3=0$. The distribution on the ceiling is the initial distribution unmodified by interflections. No light can be reflected from walls or floor. Thus, only the *interflectance* f_2 requires discussion. In this case the interflection equations reduce to

$$f_{2a}=e^{-2[k_r(h'/h)]}. \quad (8)$$

Here an exponential function is used as an approximation.

Exact expressions for f_2 can be derived for specific room shapes. For the *circular room* of height h and radius a, the *domance** $k_r=h/2a$ and the interflectance is

$$f_2=\frac{\sqrt{1+[k_r(h'/h)]^2}-[k_r(h'/h)]}{\sqrt{1+[k_r(h'/h)]^2}+[k_r(h'/h)]}. \quad (9)$$

For the *very long room* of height h and width w, $k_r=h/2w$ and

$$f_2=\sqrt{1+[2k_r(h'/h)]^2}-[2k_r(h'/h)]. \quad (10)$$

For the *square room* of height h, length and width w, $k_r=h/w$ and

$$f_2=\frac{8}{\pi}\left[\Phi\left(\tan^{-1}\frac{1}{\sqrt{1+[k_r(h'/h)]^2}}\right)-\Phi\left(\tan^{-1}\frac{1}{[k_r(h'/h)]}\right)\right], \quad (11)$$

where the function $\Phi(\gamma)$ is available in tabulated form.[6]

The first remarkable characteristic of Eqs. (9), (10), (11) is that while there is one approximate solution which applies to all room shapes having the same value of k_r, there is a *different exact solution for each room shape*. Yet all of these exact solutions are functions of k_r. Where we might have hoped for a single exact solution, we have instead a set of exact solutions, each applying to its own

*This refers to the room proportions and has been indicated by others as index of room proportion or room coefficient.

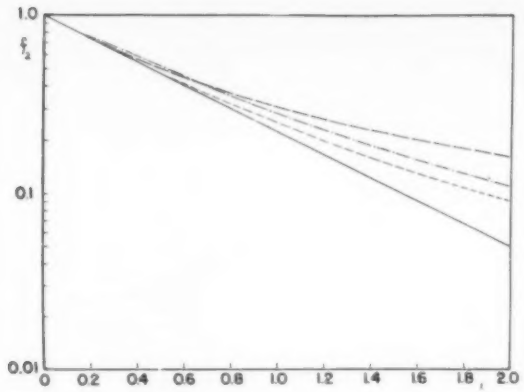

Figure 1. Interflectance f_2 as a function of domance, k_r, for rooms with luminous ceilings and black walls and floor.

Exponential approximation, Eq. (8) ————

Exact expression for

circular rooms, Eq. (9) . . . . . .

square rooms, Eq. (11) —.—.—.—

very long rooms, Eq. (10) — — —

TABLE I — Exact and Approximate Values of Interflectance in Black Rooms with Luminous Ceilings.

f_2 ($\rho_1 = \rho_3 = 0$)

k_r	Very Long Rooms	Square Rooms	Circular Rooms	Exponential Approximation
0	1.00000	1.00000	1.00000	1.00000
0.1	0.86119	0.86626	0.86083	0.86071
0.2	0.74403	0.75495	0.74164	0.74082
0.3	0.64659	0.66043	0.64000	0.63763
0.4	0.56619	0.57953	0.55358	0.54881
0.5	0.50000	0.51013	0.48024	0.47237
0.6	0.44536	0.45039	0.41807	0.40657
0.7	0.40000	0.39896	0.36534	0.34994
0.8	0.36205	0.35449	0.32057	0.30119
0.9	0.33003	0.31607	0.28248	0.25924
1.0	0.30278	0.28273	0.25000	0.22313
1.1	0.27938	0.25378	0.22221	0.19205
1.2	0.25913	0.22857	0.19836	0.16530
1.3	0.24123	0.20654	0.17779	0.14227
1.4	0.22594	0.18724	0.16000	0.12246
1.5	0.21221	0.17031	0.14455	0.10540
1.6	0.20000	0.15533	0.13108	0.09072
1.7	0.18907	0.14214	0.11929	0.07808
1.8	0.17924	0.13046	0.10892	0.06721
1.9	0.17035	0.12002	0.09977	0.05784
2.0	0.16228	0.11075	0.09167	0.04979

shape of room. *The concept of domance* (index of room proportion) *loses its unique significance.*

In Fig. 1 and Table I are given the exact and approximate solutions for f_2. Three important conclusions follow directly from inspection of Fig. 1:

(a) For very large rooms Eqs. (8) to (11) are nearly identical. The larger the room the better the agreement.

(b) For high, narrow rooms with $k_r > 0.8$ there is the largest discrepancy for very long rectangular rooms, the smallest for circular rooms.

(c) If luminous ceilings are employed in "black broom-closets," no single interflectance table can adequately represent all room shapes.

However, in the practical range $0 \leq k_r \leq 1.0$ the discrepancies between exact and approximate values of f_2 are frequently within satisfactory limits. With all types of rectangular rooms the error is less than 10 per cent out to beyond $k_r = 0.6$, and with circular rooms nearly to $k_r = 1$. Thus, for the shape rooms encountered in *large factories, large offices,* and *even classrooms, the present interflectance tables are pessimistic by less than 10 per cent, even when reflectances are very low.* It is only in the case of *very small private offices and very long corridors that the discrepancies become excessive if there are no interflections.*

A Room with High Reflectances

To investigate the character of the discrepancies which remain when interflections become important, let us consider the worst case. This will be for *very long rooms* (if $k_r > 0.6$) and the situation will be more serious, the larger the value of k_r. The majority of practical applications fall in the range $k_r \leq 1$. For a very long room, $k_r = h/2w$. Thus if we consider the case of a *very long room* with $k_r = 1$, we have an infinitely long corridor whose height is twice its width. Discrepancies for all shapes of rectangular room with $k_r = 1$ can be expected to be less than the discrepancies occurring in this case; discrepancies for circular rooms will be less than half this value for $k_r \leq 1$.

Once the choice of *very long rooms* has been made, expressions for the exact kernels can be derived. The results are

$$K_{11}(s,t) = \tfrac{1}{2} \frac{1}{(1+|s-t|^2)^{3/2}} \tag{12}$$

$$K_{11a}(s,t) = \tfrac{1}{2} e^{-|s-t|}, \tag{13}$$

where s or t specifies a distance below the ceiling divided by the width w of the room. If $k_r = 1$, $h = 2w$, then the range of values of s and t is 0 to 2. Similarly,

$$K_{21}(s) = \tfrac{1}{2}\left(1 - \frac{s}{\sqrt{1+s^2}}\right), \tag{14}$$

$$K_{21a} = \tfrac{1}{2} e^{-s}. \tag{15}$$

Also, for very long rooms,

$$\begin{cases} K_{12}(s) = 2K_{21}(s), \\ K_{31}(s) = K_{21}[(h/w) - s], \\ K_{13}(s) = K_{12}[(h/w) - s]. \end{cases} \tag{16}$$

Remaining kernels that are needed are

$$K_{32} = K_{23} = \sqrt{1+4k_r^2} - 2k_r, \tag{17}$$

$$K_{32a} = K_{23a} = e^{-2k_r s}, \tag{18}$$

$$K_{1W}(s) = 1 - \frac{[(h'/w)-s]}{\sqrt{1+[(h'/w)-s]^2}}, \tag{19}$$

$$K_{1Wa}(s) = e^{-|[(h'/w)-s]|}, \tag{20}$$

$$K_{2W} = \sqrt{1+[2k_r(h'/h)]^2} - [2k_r(h'/h)], \tag{21}$$

$$K_{2W} = e^{-2k_r(h'/h)}. \tag{22}$$

Table II and Fig. 2 show the exact and approximate values of $K_{11}(s,t)$ on the interval to be used in this example. Their difference $\Delta_{11}(s,t)$ is calculated from Eq. (2) and is given in Table II. As only integrals of K_{11} are of significance in the interflection method and the areas under the two curves of Fig. 2 are quite similar, the effect of the discrepancy tends to even out. Similar results for $K_{12}(s)$ are given in Fig. 3 and Table III.

This is as far as we can proceed without choosing specific values of reflectance. So that the contribution of interflections will be large, let us use the highest values of reflectance for which tables have been published,[7] $\rho_1 = \rho_2 = 0.80$, $\rho_3 = 0.50$. The next step is to calculate exact and approximate values of $A(s)$ and $B(s)$ for these reflectances from Eq. (1). The results are given in Tables IV and V and in Figs. 4 and 5.

It is now possible to evaluate $f(s)$, for $A(s)$,

TABLE II — Exact and Approximate Values of the Kernel $K_{11}(s,t)$ for Very Long Rooms.

$\lvert s-t \rvert$	$K_{11}(s,t)$	$K_{11a}(s,t)$	$\Delta_{11}(s,t)$
0	0.50000	0.50000	0
0.2	0.47144	0.40937	+0.06207
0.4	0.40021	0.33516	+0.06505
0.6	0.31525	0.27441	+0.04084
0.8	0.23808	0.22467	+0.01341
1.0	0.17678	0.18394	−0.00716
1.2	0.13118	0.15059	−0.01941
1.4	0.09818	0.12330	−0.02512
1.6	0.07444	0.10095	−0.02651
1.8	0.05727	0.08265	−0.02538
2.0	0.04472	0.06767	−0.02295

TABLE III — Exact and Approximate Values of the Kernel $K_{12}(s)$ for Very Long Rooms.

s	$K_{12}(s)$	$K_{12a}(s)$	$\Delta_{12}(s)$
0	1.00000	1.00000	0
0.2	0.80388	0.81873	−0.01485
0.4	0.62861	0.67032	−0.04171
0.6	0.48550	0.54881	−0.06331
0.8	0.37530	0.44933	−0.07403
1.0	0.29289	0.36788	−0.07499
1.2	0.23178	0.30119	−0.06941
1.4	0.18627	0.24660	−0.06033
1.6	0.15200	0.20190	−0.04990
1.8	0.12585	0.16530	−0.03945
2.0	0.10557	0.13534	−0.02976

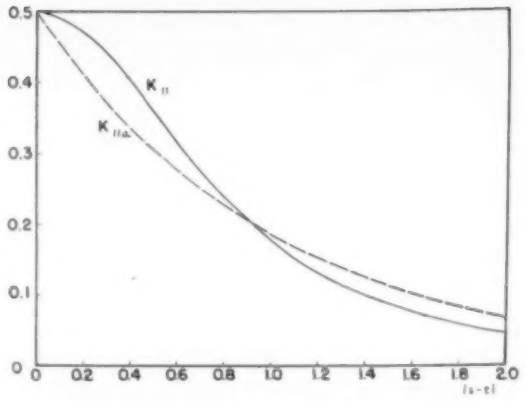

Figure 2. Comparison of exact kernel K_{11} for very long rooms with approximate kernel K_{11a}. (Eqs. (12 and (13)).

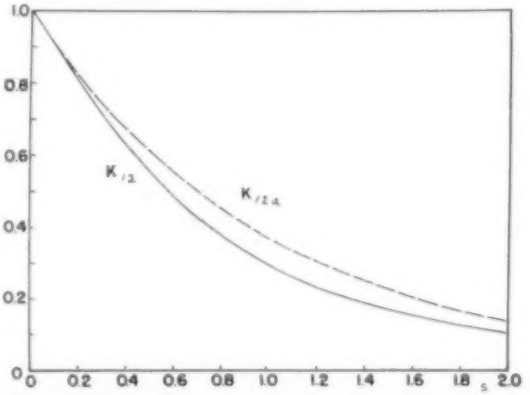

Figure 3. Comparison of exact kernel K_{12} for very long rooms with exponential approximation K_{12a}. (Eqs. (14), (15) and (16).

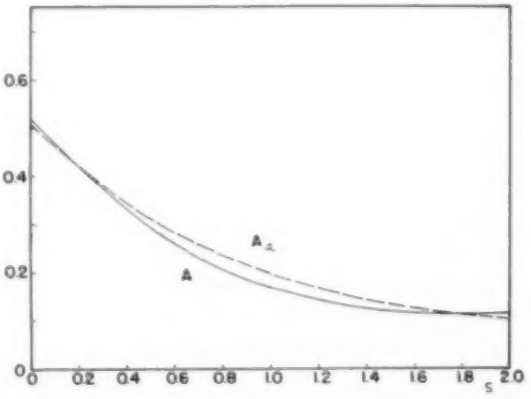

Figure 4. Exact and approximate expressions for the function $A(s)$ for very long rooms with ceiling lighting, $k_r = 1$, $\rho_1 = \rho_2 = 0.8$, $\rho_3 = 0.5$.

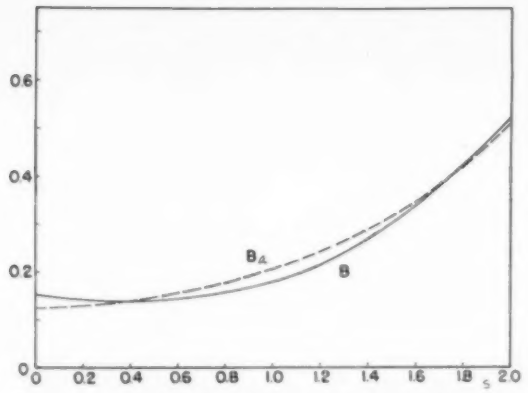

Figure 5. Exact and approximate expressions for the function $B(s)$ for very long rooms with ceiling lighting, $k_r = 1$, $\rho_1 = \rho_2 = 0.8$, $\rho_3 = 0.5$.

$B(s)$, Δ_{11}, Δ_{12}, Δ_{13} are all tabulated. The approximate solution of the integral equation is tabulated from equations[4] derived previously. The results are given in Table VI. By use of a planimeter, the function $f(s)$ was evaluated. This gives a first approximation to the solution of Eq. (14). The second approximation is

$$\begin{aligned}\mathfrak{z}_{11}(s) = f(s) &+ \rho_1 \int_0^{h/w} K_{11}(s,t) f(t)\,dt \\ &+ \rho_1\rho_2 A(s) \int_0^{h/w} K_{12}(t) f(t)\,dt \\ &+ \rho_1\rho_3 B(s) \int_0^{h/w} K_{13}(t) f(t)\,dt.\end{aligned} \tag{23}$$

Then $\mathfrak{z}_{1(i+1)}$ is obtained from $\mathfrak{z}_{1i}$ by evaluating the expression

$$\begin{aligned}\mathfrak{z}_{1(i+1)}(s) = f(s) &+ \rho_1 \int_0^{h/w} K_{11}(s,t) \mathfrak{z}_{1i}(t)\,dt \\ &+ \rho_1\rho_2 A(s) \int_0^{h/w} K_{12}(t) \mathfrak{z}_{1i}(t)\,dt \\ &+ \rho_1\rho_3 B(s) \int_0^{h/w} K_{13}(t) \mathfrak{z}_{1i}(t)\,dt.\end{aligned} \tag{24}$$

The process is repeated until two successive approximations $\mathfrak{z}_{1(i+1)}$ and $\mathfrak{z}_{1i}$ are as close together as desired. In this way, as accurate a solution as required can be obtained. The final result for the special case under consideration is given in Table VI and plotted in Fig. 6. When $\mathfrak{z}(s)$ is added to H_{1a}, the exact solution is given to an accuracy of a small fraction of one per cent. The discrepancy between H_{1a} and H_1 is at most 6 per cent or no more than 3.5 per cent of the maximum value of H_1. A little more numerical integration using Eqs. (5), (6) and (7) gives the exact solution for the remaining quantities. The final results are shown in Table VII. Discrepancies vary from 1 to 10 per cent. The interflectance and H_3 are both about 10 per cent low. The specification of the distribution of light in the upper part of the room is considerably more accurate. Whereas f_2 for a black room was low by 26 per cent, when interflections become important, the discrepancy is reduced to 10 per cent. Thus, we see that treatment of the interflected component is considerably more accurate than the exponential approximation for the direct component of f_2.

TABLE IV — Exact and Approximate Values of $A(s)$ for Very Long Rooms. $\rho_1 = \rho_2 = 0.80$, $\rho_3 = 0.50$

s	$A(s)$	$A_a(s)$	$\xi(s)$
0	0.51777	0.50830	+0.00947
0.2	0.41870	0.41802	+0.00068
0.4	0.33065	0.34451	−0.01386
0.6	0.25953	0.28484	−0.02531
0.8	0.20604	0.23659	−0.03055
1.0	0.16747	0.19784	−0.03037
1.2	0.14221	0.16701	−0.02480
1.4	0.12457	0.14292	−0.01835
1.6	0.11568	0.12454	−0.00886
1.8	0.11289	0.11116	+0.00173
2.0	0.11436	0.10226	+0.01210

TABLE V — Exact and Approximate Values of $B(s)$ for Very Long Rooms. $\rho_1 = \rho_2 = 0.80$, $\rho_3 = 0.50$

s	$B(s)$	$B_a(s)$	$\eta(s)$
0	0.15058	0.12270	+0.02788
0.2	0.14201	0.12791	+0.01410
0.4	0.13845	0.13825	+0.00020
0.6	0.14215	0.15414	−0.01199
0.8	0.15580	0.17621	−0.02041
1.0	0.17808	0.20536	−0.02728
1.2	0.21451	0.24275	−0.02824
1.4	0.26628	0.28988	−0.02360
1.6	0.33615	0.34864	−0.01249
1.8	0.42326	0.42141	+0.00185
2.0	0.52160	0.51107	+0.01053

TABLE VI — Exact and Approximate Distribution of Light on Walls of Very Long Rooms. $k_r = 1$, $\rho_1 = \rho_2 = 0.8$, $\rho_3 = 0.5$

s	$\delta(s)/H_{\infty}$	$H_{1a}(s)/H_{\infty}$	$H_1(s)/H_{\infty}$	% Error
0	+0.0173±0.0015	0.8276	0.8449	+2.05%
0.2	+0.0018	0.7603	0.7621	+0.24%
0.4	−0.0139	0.6991	0.6852	−2.02%
0.6	−0.0221	0.6435	0.6214	−3.56%
0.8	−0.0289	0.5931	0.5642	−5.13%
1.0	−0.0308	0.5474	0.5166	−5.95%
1.2	−0.0301	0.5061	0.4760	−6.33%
1.4	−0.0270	0.4688	0.4418	−6.09%
1.6	−0.0227	0.4353	0.4126	−5.51%
1.8	−0.0168	0.4052	0.3884	−4.32%
2.0	−0.0104	0.3785	0.3681	−2.82%

Corrections?

The fact that both f_2 and H_3 are low suggests the possibility of correcting these quantities for the known difference between exact and approximate

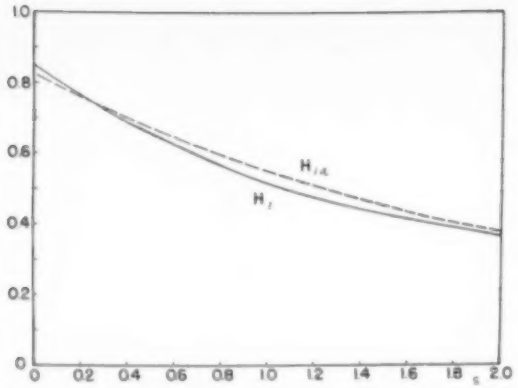

Figure 6. Exact and approximate distribution of light on walls of a very long room with ceiling lighting, $k_r = 1$, $\rho_1 = \rho_2 = 0.8$, $\rho_3 = 0.5$. Values are referred to $H_{02} = 1$.

values of f_2 in dark rooms. This amounts to correcting for the direct light from luminous ceiling to principal surface and to floor while utilizing the interflected component as given by the interflection method. Such correction factors for f_2 are readily calculated from Table I and are given in Table VIII. Similar correction factors for the direct component of light on the floor are given in Table IX.

If these changes are incorporated, Table VII gives Table X. The corrected value of f_2 is in error by less than 1 per cent. This indicates that the interflected component of f_2 is exceedingly accurate (within 1 per cent). If corrected values are used, the errors in the specification of the distribution of light in the example of Section 4 will be less than 6 per cent and the interflectance will be in error by less than 1 per cent.

The disadvantage of using the correction factors is that there are different correction factors for different shapes of rooms. If approximate correction factors for the particular room shape are employed and $0 \leq k_r \leq 1$, then f_2 can be given to better than 1 per cent for the entire practical range of reflectances. If, on the other hand, the correction

TABLE VII — Exact and Approximate Distributions of Light in a Very Long Room. $k_r = 1$, $\rho_1 = \rho_2 = 0.8$, $\rho_3 = 0.5$

	Exact	Approximate	% Error
H_{1T}/H_{02}	0.8449	0.8276	−2.05%
H_{1M}/H_{02}	0.5166	0.5475	+5.98%
H_3/H_{02}	1.4514	1.4751	+1.63%
H_2/H_{02}	0.3499	0.3154	−9.87%
f_2	0.8615	0.7739	−10.18%

TABLE VIII — Corrections for Interflectance, f_2. Δf_2 = (exact−approximate value)

k_r	Very Long Rooms	Square Rooms	Circular Rooms
0	0.00000	0.00000	0.00000
0.1	0.00048	0.00555	0.00012
0.2	0.00321	0.01413	0.00082
0.3	0.00896	0.02280	0.00237
0.4	0.01738	0.03072	0.00477
0.5	0.02763	0.03776	0.00787
0.6	0.03879	0.04382	0.01150
0.7	0.05006	0.04902	0.01540
0.8	0.06086	0.05330	0.01938
0.9	0.07079	0.05683	0.02324
1.0	0.07965	0.05960	0.02687
1.1	0.08733	0.06173	0.03016
1.2	0.09383	0.06327	0.03306
1.3	0.09896	0.06427	0.03552
1.4	0.10348	0.06478	0.03754
1.5	0.10681	0.06491	0.03915
1.6	0.10928	0.06461	0.04036
1.7	0.11099	0.06406	0.04121
1.8	0.11203	0.06325	0.04171
1.9	0.11251	0.06218	0.04193
2.0	0.11249	0.06096	0.04188

for square rooms is employed for all rooms, then f_2 can be accurate to better than 10 per cent for all reflectances and all room shapes on the range $0 \leq k_r \leq 1$.

In the general application of the interflection method the present uncorrected interflection tables may be definitely preferable to any possible corrected tables. Actual rooms nearly always contain furniture, and it has been shown[8] that the effect of furniture is of the same order of magnitude as the correction factors of Tables VIII and IX but in the opposite direction. Thus, if corrected interflection tables were employed and corrections for the effect of furniture were also included, the final result would not differ greatly from the present interflection tables. There appears to be no need to recommend corrected tables for practical applications.

TABLE IX — Corrections for Light on Floor. $\Delta((H_3/H_{02})/\rho_3)$ = (exact−approximate values of direct component)

k_r	Very Long Rooms	Square Rooms	Circular Rooms
0	0.00000	0.00000	0.00000
0.1	0.00107	0.00829	0.00027
0.2	0.00671	0.01993	0.00176
0.3	0.01738	0.03072	0.00477
0.4	0.03129	0.03990	0.00904
0.5	0.04633	0.04742	0.01409
0.6	0.06086	0.05330	0.01938
0.7	0.07387	0.05783	0.02448
0.8	0.08490	0.05527	0.02910
0.9	0.09383	0.06327	0.03305
1.0	0.10073	0.06451	0.03623
1.1	0.10581	0.06493	0.03866
1.2	0.10928	0.06461	0.04036
1.3	0.11141	0.06383	0.04141
1.4	0.11240	0.06254	0.04189
1.5	0.11249	0.06096	0.04188
1.6	0.11185	0.05904	0.04149
1.7	0.11064	0.05700	0.04078
1.8	0.10899	0.05483	0.03983
1.9	0.10701	0.05257	0.03868
2.0	0.10479	0.05031	0.03741

TABLE X — Exact and Corrected Distributions of Light in a Very Long Room.
$k_r = 1$, $\rho_1 = \rho_2 = 0.8$, $\rho_3 = 0.5$

	Exact	Corrected	% Error
H_{1T}/H_{c2}	0.8449	0.8276	−2.05%
H_{1M}/H_{c2}	0.5166	0.5475	+5.98%
H_{2}/H_{c2}	1.4514	1.4751	+1.63%
H_{3}/H_{c2}	0.3499	0.3658	+4.54%
f_2	0.8615	0.8536	−0.917%

Conclusions

The effect of the use of approximate exponential kernels in the interflection method has been investigated for rooms lighted by ceiling lighting. The approximate solution is exact for very large rooms ($k_r = 0$). Discrepancies increase as reflectances are lowered and as rooms become smaller (k_r becomes larger). Even in the most adverse case of black rooms, the exponential approximation for the interflectance is accurate to within 10 per cent out to $k_r = 0.6$ for rectangular rooms and $k_r = 1$ for circular rooms. With high reflectances the largest discrepancies occur for very long rooms and high k_r. The case of an infinitely long corridor with height twice its width is investigated in detail. The prediction of the distribution of light on the wall and ceiling is given by the present interflection tables to within −2 per cent, 6 per cent, 1 per cent (Table VII) while that on the floor and principal surface is low by 10 per cent. If similar results were calculated for different shapes of rectangular rooms, smaller discrepancies could be anticipated. For the square rooms which have been employed in experimental tests the discrepancies can be expected to be roughly half of the values obtained with the very long room. This prediction is in excellent agreement with the results of Churchill and Putnam[1] who obtained a maximum discrepancy of 4 per cent in their tests on square rooms.

It should be recognized that any tables of interflectance are inherently less accurate for very small rooms and that no single correction factor is applicable to all room shapes. This is true whether the tables are based on experiment or on theoretical calculations. Correction factors which make the direct component of light to floor and to principal surface exact for various shapes of rooms have been provided, but their use in general application is not recommended. In special cases, it may be desirable to employ them if the interflectance needs to be specified to 1 per cent and if corrections are also made for any furniture or other irregularities in the room.

The method of obtaining an exact solution of the integral equation could also be carried out for wall and floor lighting. However, as the suggested correction factors of Wiseman are of the same order of magnitude (up to 23 per cent) for all three types of lighting and his suggestion of a single correction factor for all values of k_r is both experimentally and theoretically invalid, the need for such a theoretical investigation is not urgent. It is no longer possible to attribute the Bull and Wiseman discrepancies to the use of exponential kernels. Such discrepancies are not obtained by Churchill and Putnam and the present paper lends further strength to the suggestion that the Bull and Wiseman discrepancies are of an experimental nature. Practical photometry is a very difficult subject. Perhaps, the possibility of knowing the exact solution of the integral equations will indirectly spur other investigators onward to the major progress which is needed in the field of experimental photometry.

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7. James Lee: "Interflection Tables for Rooms with Floors of High Reflectance," *Journal of the Franklin Institute*, Vol. 250, No. 5, p. 409 (November 1950).

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DISCUSSION

R. T. DORSEY:* After studying this paper and its relation to other work done in this field by investigators such as W. M. Potter, R. D. Churchill, and O. P. Meaker, it seems clear that the lighting industry now has a sufficiently accurate basis for calculations of illumination from luminous ceilings for most kinds of applications. I have one point of difference with Dr. Spencer's conclusions. It would appear more logical to have basic tables within which all know errors have been removed to cover the exact conditions assumed in the integral equations. Then, a series of factors would be developed to cover variations from these conditions. One of these is the effect of furniture as Dr. Spencer has pointed out, but there are others that are equally important, or more so, including the effect of specularity of

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finishes, differences in room shape, non uniformity of ceiling brightness, obstructions from the suspended luminaires, and the effect of columns.

ROBERT S. WISEMAN:* Dr. Spencer has again made a contribution to the mathematics of the Interflectance Theory. It is good to have the effect of the approximations for the kernel analyzed as the source of discrepancy between calculated and experimental values. Unfortunately, she has obtained the exact solution of ceiling lighting only, but perhaps the exact solutions for wall and floor lighting will be the subject of continuing papers.

It is interesting to note in the opening paragraph that the experimental investigation which is in exceedingly good agreement with the interflectance tables, is excellent, but the investigations which do not agree have been seriously questioned by Dr. Spencer. Instead of using the results as a criterion of the quality of the experimental method, one should consider the techniques themselves. If you had the opportunity to perform these experiments would you use a cell which has been corrected for eye and cosine response, which can be accurately calibrated, and which can be continuously checked for calibration; or would you prefer to use your eye, the Luckiesh-Taylor Brightness Meter, a magnesium oxide disc, and a mirror? Repeated visual measurements are tedious, tiring and subject to many variations from the inability to obtain exact matches to the changeability of the human response from day to day. I admire the stamina of Mr. Churchill's eyes in obtaining his data, and I feel that he is extremely fortunate that his results are in exceedingly good agreement, or he may have been even more seriously questioned than Professor Bull and I.

In the second paragraph, Dr. Spencer has outlined the sources of errors. This paper has considered only 1a, the kernel, and the reports by the experimenters have shown the precautions and accuracies of 3, the experimental techniques (certainly more accurate than the measurements made in the field). Instead of skipping from 1a, the kernel, to 3, the experimental techniques, as Dr. Spencer does, I would look more closely at 2, the model room, or 1b, uniformity. I suspect discrepancies might be caused by the inability of the experimenters to reproduce exactly the theoretical conditions required. If the variations from theoretical in the laboratory models have the effects indicated, what effects can be expected in actual rooms?

Again, I would like to set the record straight and remind Dr. Spencer that none of the experimental results show serious discrepancies for ceiling lighting. I only observed an average 3 per cent variation for f_2 and not 23 per cent, as Dr. Spencer persists in mentioning. The complete analysis of all experimental data was presented last year.

In both of my presentations on this subject, I have said that I believe that the accuracy of the interflectance method is great enough to be used without correction factors when so little is known about the actual specific illumination and brightness requirements. When the desired visual environment can be more accurately specified, consideration will have to be given to corrections factors or new techniques of calculation which will include surfaces with non-uniform initial brightness distributions; surfaces which are not perfectly diffusing, not uniform in reflectance, and not perfect grays; and enclosures which have contents and not empty space. Certainly the variations of the theoretical room and experimental rooms from actual rooms may reasonably result in some correction factors which will be needed when exactness is required for an illumination design.

JOHN O. KRAEHENBUEHL:* This, as a series of papers by Parry Moon and D. E. Spencer, can bring nothing but admiration for the authors' tenacity and patience in the time consuming efforts in making analytical studies of illumination. Dealing with integral equations and the ever-present kernels is no simple problem. Where the solutions for the kernels are available, the work is relatively simple; but where approximations are to be made, or unsolved conditions met, there is no way to measure the time and effort which must be expended to arrive at a solution.

In the papers and the discussions, much has been centered upon the mathematics and little upon the original premises. Mathematics is an exact language where integral equations are part of the advanced subject. Like any language, it must be subjected to all the rules of logic. Though the mathematics is exact, the solution cannot be any more accurate than the original premises established in the original expression for the related conditions. An analytical solution, by its nature must reduce the variables to a minimum or the mechanical manipulation of the mathematics is impossible. Assuming that the individual has mastered the language (mathematics), a necessity before even starting a simple problem, then the attention should be directed to the possibility of the results deviating because of the original assumptions. The attempt to obtain a true mathematical solution is to be admired but sight must not be lost of the fact that the results may deviate from actual physical conditions, not because of mathematical inaccuracies but because of basic assumptions.

Reviewing all the work of those interested in the brightness problem, both theoretical and practical, we find the names of Moon, Spencer, Logan, Meaker, Churchill, Putnam, Bull and Wiseman. These are names in recent discussions. Excellent work by others predates our present papers. Recent discussions have bordered upon controversy instead of cooperation, but the latter shows the true spirit of scientific research. Undoubtedly, no one is completely without error, and likewise, no one is completely wrong, and given a long enough time in the future, none will have but a small per cent of what is correct, and all will be shown to be incorrect for the most part.

The value of the analytical method lies in the fact that the influencing factors are brought to the fore and the degree with which they will influence the results is indicated. This permits a practical application of the resultant expression to actual problems for then the engineer has some idea what may be treated with inaccuracy, what may be neglected, and what must be given serious consideration. With a basic analytical solution and modifications through experience, a cooperative spirit between points of view leads to something that is useful, and this is the only thing that can make the work of the various individuals live. Now added to the list given above is the work of P. F. O'Brien, which seems to have promise of rather direct and simple application.

May it be that in the future there will be less bickering about small differences, and that cooperation will lead to some direct solution for engineering application. Even though the variations from actual conditions are wide, this is better than nothing. Since seeing is not, and in the foreseeable future will never be, an exact science, and as we now have a suggested ratio of 3:1, considerable deviation by

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prediction from practice may be accepted as satisfactory, and then subjected to continued scrutiny to reduce the differences between the two.

As to nomenclature, it makes little difference what names are used for any part of the science; the important thing is that these terms be defined so that there is no doubt as to the specific meaning, as applied in the science under consideration. It is more important to have methods for measuring units accurately than what particular value should be given to a basic unit, since conversion factors are available from one system to another. The profession has, from time to time, changed nomenclature, not only on a national level, but on an international level, witnessed by the change of the basic *candlepower* in both magnitude and name, and a new substitution for the term *brightness*. Therefore, the profession cannot be accused of being static.

The important thing is that we all use the same language so that communications in the art and science can be assimilated without too much mental effort, so that the facts become apparent instead of being lost in a non-conforming nomenclature — to the lay reader, gibberish. Much excellent material is lost, because only a few will make the effort to learn other than the usual nomenclature. It is understandable that for advertising purposes manufacturers and individuals create freak spelling and catch names for commercial and political reasons, but this is not the method of true science. Each professional organization has committees which will consider new units and terms, evaluate these, and submit them to individuals interested in the scientific aspects of the profession. Material should be submitted to these committees, and their decisions accepted, in the same way that the decisions of a court regulate society. Without proper regulation of the language of a science, there can be nothing but chaos in its publications and its deliberations.

The Society should limit its publications to the accepted nomenclature of its appointed committees, both in its publications and its conferences; or give to each, the privilege to compound a language to his liking, being ever mindful that nomenclature need not be static if there is *good* reason for changing some of the terms or basic units. But, we should carefully weigh the effect upon the clearness with which thought will be conveyed to the membership. The author sees nothing but confusion to the suggestion that each illumination term should have in its body some form of the word *lumen;* however, neither does he suggest that the present nomenclature should not be changed. However, we should have *one* and *only one* nomenclature made as definite and clear as possible, so that the membership, or at least the majority, can receive the benefits of that which is published and discussed. It must be realized that most members have only the published papers as part of their membership, not being able to attend the National Conferences. Even those who obtain much from the papers presented must devote considerable time to them before — if preprints are available — or after the Conference.

D. E. SPENCER:* On a logical basis, Mr. Dorsey is entirely correct. It is more logical to present the basic interflection tables in a form in which all known corrections have been made. Such basic tables can be constructed by combining Tables VIII and IX of this paper with the interflection tables of *Lighting Design*, and should be used by the illuminating engineer who wants to calculate with maximum precision.

However, the practical illuminating engineer seldom has the time to be logical. As pointed out in the paper, the original interflection tables are more suitable for his use than any "corrected" tables because they can be applied in most practical cases without correction factors.

Dr. Wiseman still seems to be reacting to my earlier comments on the experimental techniques used in his thesis.[1] I wish to clarify a misconception that has arisen. My criticisms are not directed toward the photoelectric method in general. I agree with Dr. Wiseman that it would seem preferable to employ photoelectric rather than visual techniques. However, both methods can be applied well or poorly. Churchill has succeeded in building a suitable model room and in measuring its characteristics with surprising accuracy by the visual method. Thus his paper deserves to be called excellent. Wiseman and Bull have utilized the photoelectric method. In both of their experimental results there are obvious discrepancies. Their model rooms do not satisfy the conditions assumed in the interflection theory, and their photoelectric measuring instruments are not adequately corrected and calibrated. Thus their experimental results are inconsistent and inaccurate. Dr. Wiseman misquotes me. I did not say that his discrepancy in f_2 was 23 per cent, but that discrepancies between his experimental results and the interflection method were *up to* 23 per cent, considering all three types of lighting and all quantities measured. Let me repeat, the photoelectric method is undoubtedly superior provided that it is properly used. However, this does not make all photoelectric measurements credible. Photoelectric instruments are not "cosine corrected" for all angles of incidence merely because they are labelled as such.

Professor Kraehenbuehl's call for a cooperative spirit is one that I hope all of those interested in lighting calculations will follow. I agree wholeheartedly with two of Professor Kraehenbuehl's statements: "The author sees nothing but confusion in the suggestion that each illumination term should have in its body some form of the word *lumen* . . . neither does he suggest that the present nomenclature should not be changed." How we got to talking nomenclature in a discussion of this particular paper is not clear.

*Author.

1. Discussion of "Brightness and Illumination by Interreflections in Enclosures," by Robert S. Wiseman, ILLUMINATING ENGINEERING, Vol. L, No. 10, pp. 479-481 (October 1955).

Register Early for National Technical Conference

Registration blanks for the National Technical Conference of I.E.S., to be held in Toronto, Ont., August 17-22, are being mailed to all Society members during May. Register early for this top I.E.S. meeting.

Right side of photo shows original incandescent lighting system. Results of new installation in this area prompted machine shop management to try for even better lighting in new shop (bottom of page), then under construction.

Machine Shop Relighted

INCREASED production, safer working conditions, improved employee morale, and a cleaner and better looking machine shop are the benefits realized by the Shepard Niles Crane and Hoist Corp., Montour Falls, N. Y., as a result of their relighting program.

At first, improved lighting was a secondary consideration — it went along with the major purpose of reducing the lighting load. However, management was so pleased with the results in the initial installation that quality lighting became their primary objective.

The first shop area to be relighted (photo above) was a room 68 feet by 72 feet. Levels of 10 to 15 footcandles were supplied by 36 200-watt incandescent lamps in RLM reflectors. The lighting engineer's recommendation was for approximately 50 footcandles maintained. This was achieved by the installation of 56 louvered two-lamp fixtures using 96-inch T12 cool white lamps. Units have 25 per cent uplight and 30 x 20-degree shielding. They are mounted 11 feet from the floor on 8½-foot centers. Ceiling reflectance in this area is 50%, wall reflectance approximately 40%.

With the success of this first installation, the go-ahead signal was given for the suggested lighting of a new machine shop then under construction. This area is 126 feet by 24½ feet with a ceiling height of 15 feet. Here, 48 similar units are mounted 13 feet from the floor in four rows on 6-foot centers, supplying approximately 60 footcandles with good maintenance. Ceiling has reflectance of 60%, walls 35%. Similar lighting is now being installed in 20,000 square feet of another machine shop.

The lighting engineer, who demonstrated to yet another industrial customer that quality lighting pays for itself, is L. L. Sweetland, New York State Electric & Gas Corp., Elmira, N. Y.

Application Experience With Mercury Vapor Lamps in Street Lighting Service

By JOHN W. YOUNG

THE ACCELERATING use of mercury vapor lamps in street lighting service has come about through the recognition of the economy inherent in a highly efficient type of light source; additionally, mercury lamps have demonstrated certain desirable light source features and operating advantages peculiar to the electric discharge lamp and not available in the prevailing incandescent types.

Mercury lamps of all sizes in street lighting service in the country approximate 600,000 entering 1957.[1]

A notable fact is that most of the mercury vapor public lighting has been done with the 400-watt lamp and this rating continues as highly suitable for many current lighting designs. A small percentage of installations are of 250 watts lamp size and some numbers of the 700-watt rating are now in service. Installations of 1000-watt rating are contemplated.

Interest in mercury lamps, however, now extends to the full complement of lamp sizes recommended and offered for street lighting, 100-watt to and including the 1000-watt. This family of lamps embodying both clear and color-modified types is adaptable as an illuminant for lighting the various areas and classes of streets in accordance with the ASA-IES Recommended Practice.

Lamp design refinements and fabricating techniques have brought about product improvement, evidenced by long lamp life and rising lumen maintenance characteristics. Ballasts and circuitry have been receiving increased attention. More luminaires designed expressly for mercury vapor lamps are now available.

It is the purpose of this paper to direct attention to certain developments in the broadening field of mercury lighting, including application experience by the author in his immediate previous utility connection; also, observations and evaluations of various lighting installations elsewhere. Particular discussion is given to some points on luminaire trends, the ballast and light distributions.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 9-13, 1957, Atlanta, Ga. AUTHOR: New England Power Service Company, Boston, Mass.

Lamps Recommended and Offered for Street Lighting

Mercury lamps for street lighting service have expanded rapidly in wattage ratings in recent years and now comprise a surprising array of sizes and types.

The wattage gradation of the presently composed family of lamps include:

Lamp Watts	Clear Lamp Lumens Vertical Burning
100	3,500
175	7,000
250	11,000
400	15,500 - 21,000
700	36,000
1000	55,000

These lamps and their various modifications, and lamp designations, are given in Table I.

From the predominating and well-established position of the 400-watt, 21,000-lumen lamps, design and development has broadened to larger and, more recently, smaller wattage ratings. Lamps of 700 and 1000 watts rating offer larger light packages and are capable of meeting, in instances, higher intensity lighting at lower unit cost. The smaller wattage lamps are fulfilling lighting designs as noted by some expanding use of the 250-watt lamp, an excellent lumen size in a range of lamp sizes; other small lamps designed for street lighting service are rated 100- and 175-watt, recently recognized as applicable to residential areas and light traffic streets.

Mercury lamps embody the compactness and high wattage possibilities of filament lamps. Bulb shapes of standard mercury lamps are shown in Fig. 1. Mercury lamps are easy to handle and service, a feature in luminaire design and operation. A minimum of light center lengths and the fitting of mogul bases for the complete line, tends toward simplification. In operating costs, the mercury shows marked advantages in light production as will be presently shown.

The now complete line of quartz arc tube lamps is adaptable to vertical, horizontal or other specified

TABLE I — Lamp Designations and Initial Lumen Output.
Lamps Recommended for Street Lighting Service.

Lamp Watts	Lamp Designation	Initial Lumens Vertical Burning Position
	Clear Mercury	
100	H100 — L4 or LH4	3,500
175	H175 — A22 or AH22	7,000
250	H250 — A5 or AH5 / H250 — C5 or CH5	11,000
400	H400 — A1 or AH1 / H400 — A1 or AH1 — WD	15,500
400	H400 — E1 or EH1	21,000
700	*H1000 — A15	36,500
	AH18	36,000
1,000	H1000 — A15	55,000
	Fluorescent Mercury Color Improved	
100	H100 — M4 or MH4	3,000
	BH22	6,000
250	DH5 / CCH5	9,800 - 10,000
250	H250 — JH5	10,500
400	H400 — JH1	20,000
700	*H1000 — C15	34,500
700	BH15	34,000
1,000	H1000 — C15	51,500
1,000	BH15	52,000
	Color Modified	
100	SH4 or MH4 — SW	4,000
175	SH22 ———	7,700
400	SH1 or JH1 — SW	23,000
700	SH18 ———	40,000
1,000	SH15 ———	60,000

*Operating on a ballast furnishing 700 watts to the lamp.

burning position and thereby possesses versatility in optical system design in meeting desirable candlepower distributions.

It is significant that the now available range of sizes is capable of fulfilling the same lighting now performed by the incandescent lamp. While the larger vapor lamp sizes, as expected, show the widest economic advantages, small sizes are practical and may likewise be economical; but the full complement of sizes serves to definitely raise light generation for street lighting systems to a new plateau of light efficiency.

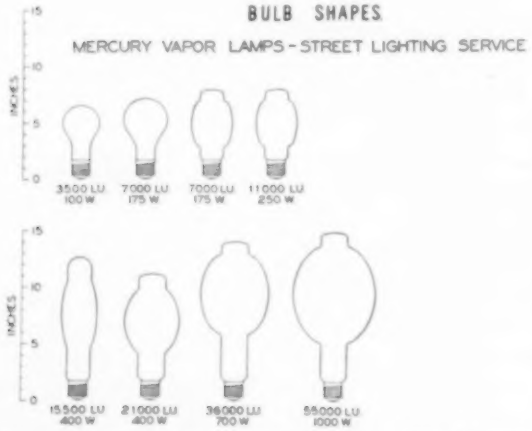

Figure 1. Bulb shapes — mercury vapor lamps, street lighting service.

Phosphor Coated Lamp Development

A recent fluorescent-mercury lamp development is of timely interest.[1a] This type improves the entire spectrum from deep violet to deep red but more importantly provides higher output and lamp efficiencies that exceed clear mercury types. In a sense it might be termed a high efficiency phosphor lamp and capable of challenging the clear lamp as the more economical.

The published ratings of three sizes of lamps that have been observed in trial installations or operated in service conditions for several months follow:

Nominal Wattage	Rated Hours Life	High Efficiency Lamp — lpw	Clear Lamp lpw
100	6,000	40.0	33
175	6,000	44.0	39
400	7,000	57.5	52.5

With respect to the property of color, the lamp offers a whiter-appearing light source that enhances the attractiveness of mercury illumination in many instances. Where light conditioning of mercury lighting has been a factor, the engineer has been reluctant to sacrifice light output as exists with bulb coatings that are specified as "color corrected" or "color improved," which yield good color. Now efficiency is compatible with some color modification that contributes appearance-wise to lighted luminaires and their surroundings.

The trend in efficiency is expected to rise with further developments in this type. Such progress increases the economic position of the smaller sizes of lamps particularly in meeting footcandle levels where only minimum illumination can be justified.

Certain points on the application of this lamp under service conditions are given in a later section.

Essential Lamp Performance Characteristics

In the evaluation of lamps, suitability and performance may be viewed by the user in terms of the essential lamp characteristics of (a) Efficiency, (b) Life, (c) Lumen Maintenance. Reference will be confined to certain pertinent points since a full coverage of the subject matter is beyond the scope of this discussion.

The property of efficiency, that is, lumens per watt, is a prime advantage of mercury lamps that has contributed (with other electric discharge lamps) to a new light production era. Fig. 2 sets

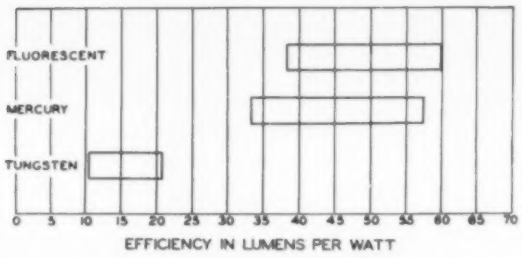

Figure 2. Range of lamp efficiencies. Incandescent, mercury vapor and fluorescent lamps recommended for street lighting service.

forth the mercury lamp in relation to street lighting incandescent and fluorescent lamp efficiencies.

The properties of life and lumen maintenance[2] may be more adequately treated together since the light output is definitely related to the in-service burning hours of the lamp. Average life has increased consistently and now stands at 6000-7000 hours for street lighting types.

A feature of mercury lamps is that they generally have a longer useful life than their rated life. Reports of field experience evidences a trend toward exceeding the present ratings. In specific terms, 8000 hours average, or two years in service, has been attained in some instances. Although not evaluated as to useful life or economic value, groups have been operated 10,000 to 12,000 hours in service.

Long burning hours serve the application engineer to advantage in system operation, and the experience data shown in Fig. 3 are necessary for sound economics in light production in service. The lumen maintenance performance of the sample, with average life for the group at 8800 hours, is representative of the lamps of this manufacturer in service during the immediate past period. Though the light output performance is superior to that of a few years past, more recent lamps show improvement over the sample as given.

As to other lamp sizes, the 250-watt, followed by the 100-watt, have over several years' application demonstrated life exceeding somewhat that of the 400-watt quartz tube lamp. It is expected that 175-watt lamp will perform in line with the other two small sizes as to life, and improvement in the lumen maintenance characteristic of the three is progressing.

Ballast Considerations

The necessity of auxiliary equipment for the voltage-current control of a vapor lamp demands consideration as to electrical characteristics in deriving satisfactory lamp operation. Likewise, certain mechanical aspects of such equipment are important; though it may be comparatively small in physical size as equipment goes, it still may prove awkward as to mounting location. But of more concern, the installed cost of ballasts for both the large and the small lamp ratings equals and frequently exceeds that of the luminaire itself. Thus, this equipment is cited as meriting consideration of its influence on the economics of mercury lamp installations.

It is not my intention to review the various electrical design factors of ballasts or the circuitry and choice of system; this is beyond the scope of this paper. Lamps may be operated through individual transformers from constant current series circuits or directly from secondary series circuits of moving coil or static-type regulators with auxiliary devices. Multiple primary supply of an individual ballast serving a lamp predominates in mercury lighting installations.

Of the factors, however, of multiple ballasts that determine the design and price of the product, the starting voltage is of particular current interest. The starting voltage characteristic of a lamp-ballast circuit has been under continuing clinical treatment by lamp and ballast designers for some time. The requirement to be met is the minimum voltage for satisfactory starting of lamps outdoors under the cold weather temperature conditions in which they may operate. And the provision of open circuit voltage has a direct bearing on the size and weight, and likewise cost, of the ballast — in short, there is a price for building-in open circuit voltage, especially for equipment to start lamps at −20 and −30° F.

Some investigation has been carried out on open circuit voltages for reliable starting.[3,4] The conclusion of Binder is that temperature conditions

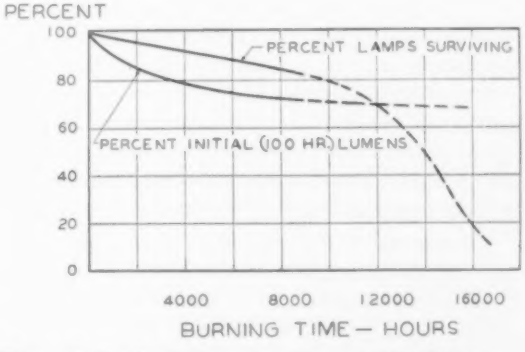

Figure 3. Performance of a group of 50 E-H1 lamps in field service at 8800 hours burning time.

are not as severe as has been assumed in the past and that previously recommended voltages for outdoor installations are higher than need be, especially for the H400-E1 lamp. Furthermore, in only a few locations in this country, and but a few days of the year in these areas, does the temperature fall below −15° F at lamp starting time.

The earliest applications relied on ballasts, of the leakage type, having 220-230 volts open circuit for outdoor starting of the 400-watt A-I lamp.[5] Published data and field experience in certain areas have turned attention for some time to the adequacy of starting voltages in the 220-240 volt range, operating the lamp auxiliary directly from distribution mains at 240 volts. The maximum voltage available for starting is, of course, the line voltage of 240 volts.

Such operation may be accomplished by a reactor or "choke" as frequently termed, in series with the lamp and this lamp-ballast circuit connected directly across the 240-volt mains. Two principal advantages of this simple device are the small physical size of the core and coil assembly and the inherent low losses.

An investigation was set up by the lighting personnel of the New England Electric System on the practicability of chokes for the 100-, 175-, 250- and 400-watt lamps. Two bases of lamp performance must be known for such application: the statistical variation of starting voltages with temperature in which starting voltage increases rapidly as the temperature decreases and the frequency of the coldest temperatures to which lamps will be subjected for the starting operation. The climatic characteristics considered for the use of chokes are those experienced in the southern New England states.

Lamp manufacturers' test data such as was available was studied and analyzed. To derive some first hand data, groups of standard 100-watt, L-H4 and 175-watt, A-H22 lamps of three manufacturers were put through cold box tests, the results showing instant starting on 240-volt chokes down to the region of 0° F. Delayed starting varying from several seconds to twenty minutes took place at −15° F with only one out of six lamps failing to start in that period. Investigation is underway on starting and operating 250- and 400-watt lamps on chokes.

To confirm the laboratory tests, groups of 100- and 175-watt lamps in commercially available luminaires equipped with reactors were operated in regular field service on 240-volt distribution secondaries during the 1956-57 winter months. All lamps started instantly and consistently, on two occasions at 0°F and 2°F during the unusually cold part of the past season.

The results to date indicate the practicability of starting the 100- and 175-watt lamps at 240 volts at temperatures down to 0° F which situation it should be noted from historical weather data occurs but a few times during the winter; for example, only twice during the past season. The variation in temperature on all other winter days at lamp starting time would range 5° to 15° F on colder days but with a high percentage of days in the 15° and 30° F and higher bracket, allowing an almost indisputable margin for reliability of starting.

As for the choke, such type would be of low power factor type, of around half the weight and size, half or less the losses of the leakage ballast design, and less cost to manufacture. The choke also may be a non-compounded encased assembly, suitable for placing in street light heads and luminaire housings with but moderate ambient temperature problems from core and coil losses. Power factor correction is a distribution system problem as LPF corrective measures may be more economically provided by distribution line capacitors than by incorporating capacitors in individual ballast designs.

The potential for reactors seems sizable and the objectives of savings in operation and the physical adaptability in luminaires for a lamp auxiliary of this nature is an urgent matter for the ballast designer and his ingenuity.

Luminaire Operating Cost Comparisons

As the first step in an economic analysis of street light operation, comparisons may be made between luminaires[6] of a given light source type and, significantly, between luminaires of differing light sources as well.

In Fig. 4 are given the results of one such study, multiple system equipment in this instance, mercury vapor compared with the familiar incandescent. Luminaires are commercially available types, conforming to IES Classification of Luminaire Light Distributions, each unit selected to meet a typical street width within the luminaire design qualifications.

The cost is composed of three parts:

(A) Fixed cost and maintenance of the Luminaire (Less lamps)
(B) Electrical Energy Cost
(C) Lamp Replacement and Labor Cost

The total is the cost of the generated or "raw" light produced by each luminaire and resolved in

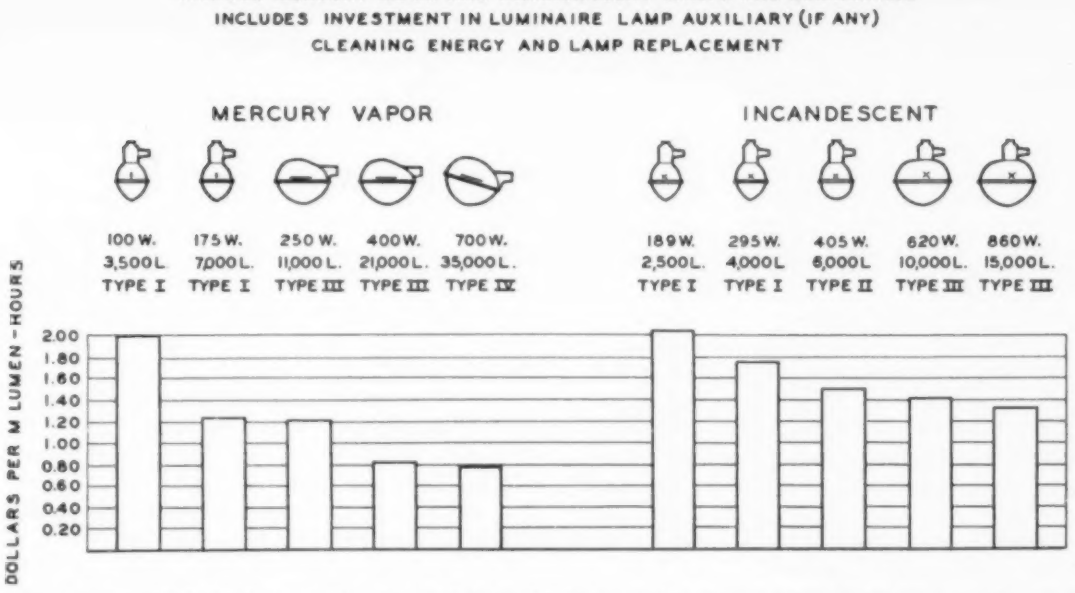

Figure 4. Street light luminaire study. Cost of light production; carrying charges taken at 15 per cent. Lamps at 30 per cent from List Price. For the purpose of this example, electricity taken at the lowest conceivable rate of 1½ cents per kw-hr.

terms of the cost in dollars per one million lumen-hours, a convenient light production cost unit.

Obvious findings may be taken from such data. The mercury group demonstrates the wide economic advantages in light production compared to the familiar incandescent, the spread between the larger sizes, above the 10-11,000 lumen level being especially marked. But the area at and below this rating is of interest as well. As is evident, the 100-watt alone, probably the smallest practical size for street work, does not show an appreciable difference with the filament near its ratings. However, two pertinent observations apply here: first, mercury lamp efficiency developments (as with the 100-watt "white" phosphor-coated lamp, now rated 4,000 lumens) will increase the advantage of this and any of the smaller lamp sizes compared to incandescent counter-sizes; second, lower cost auxiliaries, such as reactors, and the low inherent losses will widen the margin in favor of mercury still further. Such factors may be duly assigned to other appropriate lamp sizes as well.

This form of analysis lends itself to a broad scale study of light production cost for large projects and even entire systems and communities; it is especially useful in selecting the largest practical lamp size that will fulfill the designer's problem.

Having determined the cost of the generated light for luminaire as selected, the application of luminaire utilization and maintenance factors follow and calculations are carried through to the annual cost of furnishing the effective lumens required for the final lighting layout. Comparisons between lighting systems usually must be qualified due to the variables in field conditions, technical solutions and construction and operating practice. But as stated in a previous paper[7] mercury vapor serves to upgrade lamp sizes of an existing incandescent system and experience continues to bear out that result. This practice is effected in two respects: by furnishing effective lumens at a lower dollar cost and the ability to meet higher intensities and distribution patterns with a minimum of lamp installations. Two examples may be cited: A 50-foot width street, lighted to 1.2 ft-c average, maintained, with the 21,000-lumen lamp, shows the cost of the effective lumens per 100 lineal feet of street as approximately 60 per cent of that were the 15,000-lumen incandescent source used. A recent installation of the 175-watt, 7000-lumen lamp compared with the 6000-lumen incandescent, shows the cost of the required effective lumens per 100 lineal feet of street at around 80 per cent for mercury compared with incandescent.

Further promotive of savings in mercury installations by reason of reductions in investment is the feasibility of completely unitized luminaires—lamp and luminaire, reactor and control device (if

multiple) — mounted in the field as a single piece of equipment, horizontal or vertical lamp designs alike. Units up to and including 400 watts are thus adaptable and workable.

Application Practice

Substantial experience has accrued to date with mercury street lighting in all areas now served by filament lamps. An appraising glance at developments discloses the steady augmenting of luminaires expressly designed for the mercury concentrated light source, luminaires with larger prismatic areas, high utilization values, the addition of horizontal (or approximate) lamp luminaires for 100-, 175- and 250-watt lamps. A further advance is a luminaire with the optical system designed for large wattage phosphor coated lamps. And a new departure in design utilizes diffusion-reflection of a vertical lamp positioned luminaire observed experimentally for highway lighting.

Commercial and business areas introduced mercury as a desirable public way lighting source and extensive installations are now serving these areas. The prime qualifying factor is the economy in furnishing high lumen lighting demanded on such streets. Not least in importance is the public's tendency toward more attractiveness in lighting and the attention to aesthetic features, provided in a high percentage of cases by the clear mercury lamp. But a prospective application note is color treatment as added enhancement of lighting, achieved with the "white" phosphor coated lamp.

The applied footcandle values have shown a gradual rise from the recommended minimums as the desire for stronger lighting effects has continued to grow. Light distributions are generally Type III and IV and served by the 400-watt lamp as a general thing. Potentially, 700-watt lamp sizes will suitably meet expected further desired intensities and in so doing conserve the number of lamp units. Shorter spacings prevail in commercial areas, ranging from 85 feet or so to wider spacing of 100 to 115 feet generally. Mounting heights have been looked upon as highly important, 30- to 32-foot light center height, to insure good uniformity of distribution with minimized glare.

Traffic streets quickly followed commercial areas with mercury installations, the 400-watt lamp predominating. Lighting has expanded and is now being applied throughout the several traffic street classifications. Luminaire light distributions, Types II and III generally prevail.

The significant justifying factor, again, is the economy in meeting the required footcandle intensities. Much traffic street lighting is provided on distribution line poles, served by overhead circuits, and the solution is quite generally a lamp-for-lamp arrangement. With such situations the investment in utilization equipment is virtually the same for either mercury or incandescent lamps. The savings in operation in favor of mercury is of the order of the energy component per lamp.

In the pursuit of competent lighting arrangements, mercury equipment has proved versatile and adaptable to a wide range of street widths — 28 to 90 feet curb to curb — with linear spacing of units conforming to desired intensities and light distribution uniformity on the street surface. In some luminaires, precise alternate lamp positioning with respect to the refractor, and reflector combinations if required, produce optical designs that give suitable light distributions for a variety of street widths. Three lamp sizes 175-, 250- and 400-watts may thus be used in the same luminaire for various street classifications.

Mercury lamp color properties for the sake of color rendition have not been important on traffic streets. Coated lamps, however, tender some refinement in light distribution and brightness control in certain luminaires that ordinarily use the clear lamp. Increased diffusion in the optical system thus cuts back candlepower at the high angles in the modification of the isofootcandle pattern and, of course, is satisfactory where spacings of units will maintain the distribution pattern to an adequate degree. But a material reduction of the dazzle and the scintillating effect about the luminaire may thus be obtained. A practical coated-lamp application is on slopes and grades in reducing glare at certain angles objectionable to the driver-observer.

Mounting heights for high lumen lamp lighting are of particular concern with the larger lamps, with 31- to 32-foot light center height insuring uniform distribution over the lamp station area and a minimum of "blinding effect" or glare.

Residential Streets — Lighting Design

Mercury lamp lighting has been extended to purely residential areas. An example of an all-mercury lighting project in a typical residential section of a large city is shown in Fig. 5. Lamp sizes in this layout are 3500- and 7000-lumen, the latter applied initially on light traffic streets and at important intersections. The layout contemplates the 7000-lumen lamp throughout eventually, with intensities calculated as varying 0.25 - 0.35 ft-c avg., maintained.

The Type I distribution luminaire mounting at 26 feet and spacings varying 150-200 feet or at 6

Figure 5. Residential area lighting project. Lamp arrangement for a pilot residential area lighting project to determine primarily acceptable light distribution patterns. Light traffic streets and important intersections — 175-watt mercury lamp; residential access streets — 100-watt. See Fig. 6 for view of typical streets.

to 8 spacing-height ratio to fit somewhat irregular street lengths and frequent intersections, meets the economic conditions presented to the designer. Particular effort was exercised in this layout to obtain effective light distribution on the street and adjacent areas, by evaluating various luminaire types, their light distribution design and proper installation. In this consideration, the objective of truly minimized glare was stressed. As to results, the phosphor-coated lamp has potential value in furnishing increased effective lumens for the same span as clear lamps; also, the use of the 175-watt coated lamp may have added value by lessening the candlepower at the high angles to comfortable proportions, in both vertical and horizontal luminaire types.

Two views of the light distribution on typical streets in the arrangement in Fig. 5, are shown in Fig. 6. Strong pavement brightness effects and the transverse light control are to be noted. Although judged as signally acceptable, no conclusions are to be drawn as to the degree of visibility furnished in this case, as it is subject to further luminaire trials and evaluation. As to specific luminaire design properties, the candlepower distribution of the 100-watt lamp, vertical burning position in a Type I luminaire with an optical system designed for filament lamps, is fully satisfactory; likewise, a narrow Type II distribution which will be referred to shortly. The high vertical angles of light distribution afford effective pavement brightness, likewise, brightness of objects and reflected light from physical features along the roadway. Candlepower at the maximum beam and at high angles is moderate and glare is a minor factor. The 175-watt lamp when used in a horizontal luminaire (Fig. 6) of sufficient glassware area produces excellent results as to glare control. Mounting height of high verti-

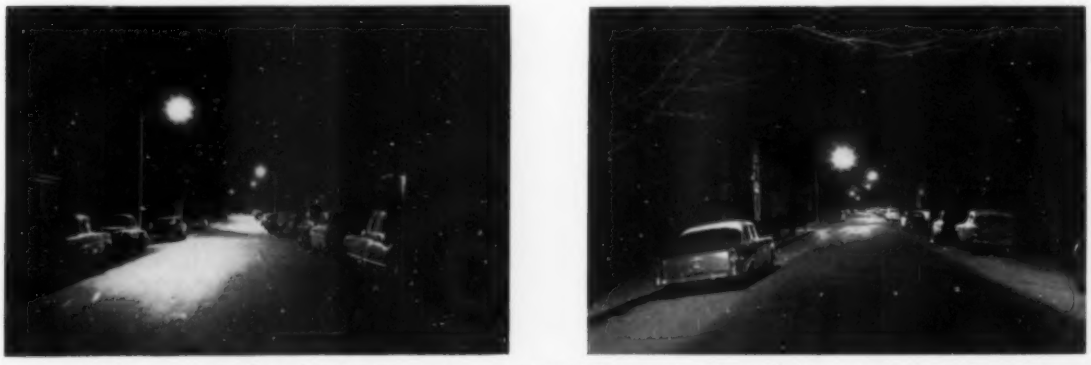

Figure 6. Views showing light distribution results on residential streets in Fig. 5. Left — 175-watt, horizontal lamp luminaire, .35 ft-c average. Right — 100-watt, vertical lamp luminaire, .12 ft-c average. Maintained values in both instances.

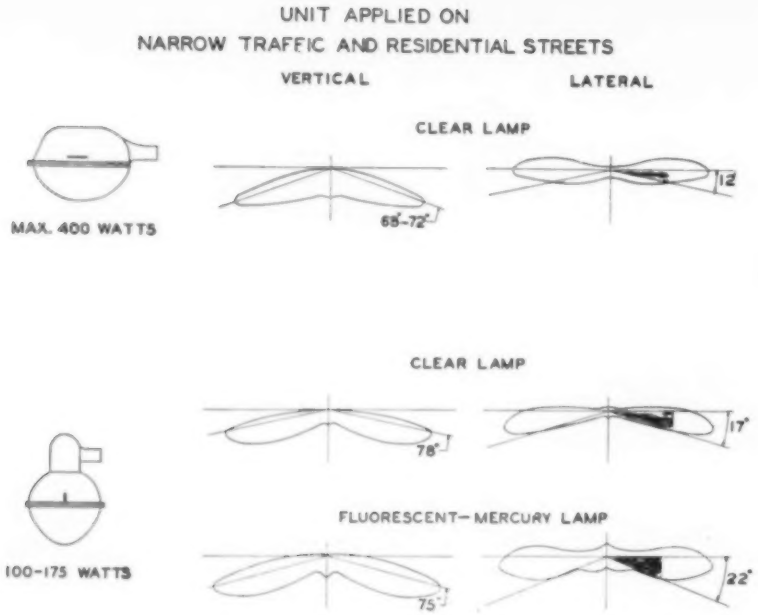

Figure 7. Mercury lamp luminaire light distribution characteristics.

cal angle luminaires is important, the 26- to 28-foot level being satisfactory for spacing-height ratios of as much as 10.

The overall effect of well distributed light, between curblines, and on adjacent areas including sidewalks assures convenience and safety for pedestrians. The superiority of specific light distribution as by refractor units is obvious even with small lamps and luminaires of modern design, compared to "spot" lighting patterns of inferior equipment.

A type of distribution that has been explored with success on roadways of 26- to 35-foot curb to curb widths for large and small lamps is a narrow asymmetric light distribution having a lateral width of 12° to 22°. Such type contrives high utilizations on the roadway surface and with control of back and lateral lighting representative of Type I. It is especially suitable where residences are involved. This arrangement permits mounting luminaires on-one-side and near the curb line, requiring short luminaire supports in place of supports for center or near-center of road mounting.

Two distributions are shown in Fig. 7. The hori-

Figure 8. Commercial area installation using the 400-watt, S-H1, 23,000-lumen lamp. Lighting design data: IES Type III Distribution, spacing 60 ft. curb to curb, 30 ft. M.H., 2.00 ft-c avg., maintained, calculated.

zontal large lamp luminaire has been applied on narrow streets usually through residential areas where the vehicular volume dictates traffic street lighting levels of as high as 0.8 ft-c avg. and good uniformity of distribution to provide a high degree of silhouette lighting and direct discernment as well. Lamps are spaced up to 200 feet and at light center heights of from 31 to 32 feet for the 250- and 400-watt sizes.

Experience indicates vertical angles of maximum candlepower at 68° - 72° as desirable to obtain uniform pavement brightness which with the high mounting minimizes glare from the angles of maximum candlepower. It is likewise to be noted that the use of phosphor coated lamps in instances may be employed to reduce glare.

The second distribution in Fig. 7 pertains to residential streets. Trial and observation of equipment indicates that a high vertical angle, 77° - 79°, fits the frequent practice of spacing smaller lamps at 200 feet and is applicable to 250-foot spacing. Trials with coated lamps show a lowering of the vertical angle of approximately 3°.

Conclusions

The use of mercury vapor lamps in street lighting service is expanding rapidly. The complete family of lamp sizes now available is capable of meeting the varied lighting demands on all classifications of streets and highways, offering high lamp efficiencies and versatility in lighting effects through color modification of clear mercury types. It is hoped that the presentation of this material will stimulate interest and discussion on mercury lamp equipment and the evaluation of operating practice and procedure. Specifically, more effort is needed on ballast designs and their mounting in luminaires, a wider knowledge of the economic factors is highly desirable, and refinements in luminaire light distribution properties are always in order.

Acknowledgements

The author greatly appreciates the permission of the New England Electric System to use much data and information without which this paper would not be complete. Acknowledgement is also made of the contributions of J. A. MacCracken and C. E. Whitaker of the New England Electric System and to representatives of lamp and equipment companies for assistance with certain data.

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6. American Standard Practice for Street and Highway Lighting. Appendix D. Definition — "Luminaire — a complete lighting device consisting of a light source together with its direct appurtenances, such as globe, reflector, refractor, housing and such support as is integral with the housing." Note — where a lamp auxiliary is involved, as a ballast, its cost whether mounted integrally or separately has been included as part of the luminaire cost.

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DISCUSSION

D. A. TOENJES:* This paper is especially welcome for the fact that it is written from the point of view of a lamp user and thus describes the lamps in terms of service experience. Prospective users of mercury lamps in street lighting should find this a helpful guide.

The question of choosing the most economic service life of mercury lamps in street lighting needs the benefit of the experience of street lighting users such as Mr. Young. Probably in street lighting this choice will show wider variation than it will with industrial lighting. The reason is that in street lighting service there are wide differences in operating costs, such as truck-and-time costs of replacing individual lamps between group-relamping intervals. Mr. Young mentions that an average useful life of 8000 hours has been attained in some instances. Does he regard this figure as typical? Fig. 3 indicates that about 15 per cent individual burnouts would be experienced over this operating interval.

Our information from a fair cross-section of street lighting lamp users, particularly with the H400-E1 mercury lamps, has been that they have chosen from 4000 to 6000 burning hours as their relamping interval. The 6000-hour figure has been typical of conventional street lighting installations, while the 4000-hour interval has been used with lighting of interchanges and service plazas on turnpikes and expressways, and remote highway intersections, where truck-and-time costs of individual relamping are higher.

We question the statement in the paper that the increase in luminous efficiency of the 100-watt "white" phosphor-coated lamp over that of the clear lamp will increase its advantage over incandescent lighting in similar sizes. While the phosphor coating does improve the luminous efficiency, the optical control is seriously reduced. To some degree this may be compensated for by an optical system designed specifically for this diffuse light source.

In the larger mercury lamp sizes — for example, 700 and 1000 watts — there is undoubtedly some justification for use of the coated lamp to reduce the high candlepower from the luminaire. We would expect this to be especially true for luminaires with smaller projected area of glassware, and for applications where precise control of light is not essential, such as parking lots or very high-footcandle street

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lighting installations. If the main purpose is to reduce candlepower, could it not be done more efficiently by a redesign of the optical system of the luminaire, to use the clear lamp?

If improvement of color rendition is the objective, then the regular design of the improved-color lamp is markedly superior to the more efficient "white" phosphor-coated lamp. Surely there is broad application for the "white" lamp with such applications as industrial lighting, where light control is not so much needed. But in street lighting, the clear mercury lamp remains important where light control is most desired, and the regular improved color lamp, while subject to the penalties of less optical control and reduced light output, does provide the best color rendition that has been achieved with mercury lamps up to the present time. A street lighting user who chooses to apply the "white" phosphor-coated lamp should fully realize the compromise that he is making.

With regard to these three available designs of mercury lamps, we are hopeful that street lighting users will eventually decide, based upon their experience, that two of these lamp designs are sufficient for all street lighting applications. Probably they would include the clear lamp and one of the phosphor-coated designs.

C. E. Waldron:* The rapid growth in the use of mercury vapor lamps for street lighting certainly is a vindication of some sort for those in the street lighting business who have pioneered in this type of lighting, and of these pioneers, John Young has made some excellent and important contributions. His paper is the result of his experience and investigation into the subject, coupled with a serious desire to improve the quality of street lighting and to maintain this quality.

Some of us have been a little slower to adopt the mercury lamp for street lighting, and perhaps with good reason. As with most things, however, conditions change and reasons which were once valid may become less valid as improvements are made in lamp life, lumen output and maintenance thereof through a longer period of lamp life.

To the utility company supplying street lighting to municipal customers it makes little difference in the customer's cost whether mercury with higher equipment cost and lower kwhrs or incandescent with lower equipment cost and higher kwhrs is supplied, assuming that you get nearly equal lighting result. Saving of kwhrs is often more than offset by the need to collect taxes and earnings on the higher investment.

This picture is changing. With improvements in the mercury lamps, new methods of ballasting and increased use of such equipment, it is expected that mercury street lighting will continue to show more favorably in economic and lighting comparisons with incandescent applications.

Mr. Young states that "phosphor coated lamps in instances may be employed to reduce glare." With this there is no argument. I have tried the 175-watt clear mercury lamp in Type 2 refractor at 26- to 27-foot mounting height and find the brightness too much for comfort.

When using the phosphor coated mercury lamp in street lighting, the spacing between luminaires may have to be adjusted downward and careful choice of equipment will be necessary to maintain the desired lighting level and uniformity, due to loss of light control with the phosphor coated lamp as compared to the clear mercury lamp.

*Niagara Mohawk Power Co., Albany, N. Y.

In this respect we are finding that increased emphasis is being placed on color correction in mercury lighting, not only for street lighting in the business areas, but for all street lighting. Satisfactory color resolution is most important in identification of clothing, vehicles, license plates, etc., where police or witness reports and descriptions become necessary. For this and other reasons, all mercury street lighting considered in my recommendations is for improved color lamps.

We also find that it is generally poor economics to operate mercury lamps with ballasts on series circuits. All of the 400-watt mercury street lighting now installed and planned for installation in my company is and will be served from 120/240 volt distribution. The only mercury lamps on series circuits would be where existing circuits are economical to maintain and then only in the 100-watt and 175-watt sizes.

K. W. Fisher:* Our experience with mercury lamps has been confined to the 250- and 400-watt sizes. I feel there is very little I can add to what the author has already pointed out. I would like to verify the fact that the average burning hours for the two size lamps mentioned above are considerably higher than the rated life set forth by the manufacturers at the present time. We have a number of lamps in operation in our system which have been in service well beyond 12,000 hours of burning time. There is, of course, the question which has never been settled to any degree of satisfaction, as to just what point in the relationship of the hours of burning time a mercury lamp should be replaced due to loss in light output.

As has been pointed out by the author there is definite need for further ballast considerations in view of their present cost and size as compared to the cost of a complete luminaire. It would be most desirable, as well as practical, to have a ballast small enough and light enough to mount in the head of luminaires using mercury lamps. We have had no objection, whatsoever, in our territory to the use of standard blue mercury lamps; therefore, before improved-color lamps are used, a careful study should be made to determine if the additional cost of the improved-color lamps over the standard blue lamps is jusitfiable.

While there are mercury lamp sizes available for application in residential areas, it is very questionable at this time whether or not, due to increased costs of small mercury lamp installations as compared to small incandescent lamp installations, the mercury will be accepted for some time to come.

R. R. Wylie:** Twice now in the past two years manufacturers and users of street lighting have had the opportunity of having the highlights of the accumulation of John Young's experience as an installer and user of street lighting presented to us. This year these highlights present a new challenge for the future. This challenge is based on the work which Mr. Young has started and which he gives us today as a consulting engineer. These principles will be carried out in the future in the lighting of America's highways.

It should be emphasized in reviewing Fig. 2 that the author is discussing only lamp efficiencies. Tungsten sources are not as bad as they might appear, when we consider the illumination delivered to the pavement. As refractor designers will point out, this is because of the high optical efficiency of a point or small source. Conversely, fluorescent

*Appalachian Electric Power Co., Charleston, West Virginia.
**Sylvania Electric Products Inc., Salem, Mass.

lighting is not as good as it looks, because of the impracticability of obtaining good control with refractors or reflectors in economic combination with practical sized equipment. Much of the light does not get onto the pavement. As a practical user Mr. Young points out mercury is the best compromise. This compromise is at its best with the clear lamp and is modified somewhat with the color-modified sources.

In order to enhance the value of this noteworthy contribution, it would be interesting to have a break-down of the cost figures. In other words, what would happen if energy rates were very low? Under "Luminaire Operating Cost Comparisons," it is not quite clear whether or not the costs have been developed for the 100- and 175-watt lamps, incorporating the use of the lower cost auxiliaries, such as reactors or chokes. We believe that a further development of the cost structure, using conventional ballasting equipment, as well as the choke type reactor, would prove beneficial to users.

One further point which has been brought out in the paper should be emphasized in its discussion. That point, a benefit to every user, is the economies which may be realized in an installation by the unitizing of equipment over conventional installation procedures.

W. B. ELMER:* In the opening of this paper the author comments on the accelerating use of mercury vapor lamps in street lighting service, and in the development of his subject he presents a scholarly picture of why and how mercury lighting is destined for an ever-increasing place in the overall street lighting picture. The author has modestly failed to bring out the fact that he, personally, was one of the early street lighting engineers to recognize the possibilities of mercury lighting and has done a tremendous service to our industry in exploring its applications and promoting this type of lighting generally.

In the opening sentence, Mr. Young mentions certain desirable light source features of mercury lamps. Not the least of these desirable features which deserve inclusion, particularly under his "residential" section, is the Purkinje effect. This is the name given to that property of the human eye which shifts its sensitivity toward the blue end of the spectrum under very low levels of intensity. For this reason, mercury lighting with its strong blue component has a decided advantage over incandescent lighting wherever the intensity is low enough to come under this Purkinje shift. This would be true in most of the fringe areas in residential districts where the luminaires in general are small and spaced fairly far apart and where people located in the outlying environments such as backyards, driveways, side streets, etc., are functioning in extremely low levels of illumination. It is undoubtedly true that this natural and often unrecognized characteristic of the human eye is responsible for the general acceptance, by the public, of what is otherwise a very poor spectral source.

In describing the complete line of mercury lamps, the author mentions that the fitting of mogul bases for the complete line tends toward simplification. It is unfortunate, however, that the 100-watt size was not provided with a medium base which would result in better equipment design and a less expensive initial cost as well as lower lamp replacement cost. From Fig. 4 it is evident that the 100-watt mercury lamp size can barely show an economical advantage over the 2500-lumen incandescent lamp. The use of open reflectors (which is unfortunately omitted in the Fig. 4 diagram) reduces the initial cost so that the 100-watt mercury vapor lamp would show a greater superiority if provided with both of these features. The 100-watt lamp has proved to be very satisfactory in a suitable open reflector.

Perhaps in a rebuttal the author would be willing to provide an explanation or a correction of the following points in Table I. First, the SH4 lamp is shown as a designation for both the 100- and the 175-watt color modified type. Secondly, the 100-watt fluorescent-mercury improved color lamp is listed as the H1000 which presumably should be the H100. Also, the use of the symbols MH4 and JH1 duplicated in different portions of the table could lead to considerable confusion on the part of the users and it is hoped that the manufacturers of the respective lamps can find some way to avoid this source of confusion. On page 258 under "Application Practice" the author mentions the new diffusion-reflection principle now coming into substantial use in a new luminaire suitable for mercury lighting. This new diffusion-reflection luminaire, usually called the "linear low brightness luminaire" makes it possible to use the compact mercury lamp instead of the elongated fluorescent lamp in a low brightness street luminaire. The excellent optical control provided by this design should eventually supersede most discrete fluorescent street lighting with its unfortunate lack of optical control.

In the second paragraph under "Application Practice" it might be of interest to mention the yellow mercury lamp which will undoubtedly find considerable application as a substitute for the sodium lamp in applications requiring marking or warning of hazardous conditions.

In Fig. 6 it is unfortunate that the two pictures were not taken in a similar relationship to the luminaire locations. It appears likely that the difference in pavement brightness would entirely disappear if both pictures were taken the same distance from the luminaire. Possibly, new pictures could be included in the rebuttal. On page 260, the author mentions "the superiority of specific light distribution as by refractor units." It should be recognized that the refractor-reflector principle is a very inferior one from many points of view, such as (1) poor control of transverse and upward light, (2) extreme non-uniformity of luminaire brightness, and (3) inefficiency and limited angular control from a stepped prismatic surface. The new diffuser-reflector principle overcomes all of these difficulties and will probably supersede the reflector-refractor principle in the course of time.

In general, the glare from mercury street lighting is much more serious than is acknowledged in this paper although this is not a defect inherent in the mercury lamp itself, but rather in the type of luminaires commonly used at present. With the general adoption of low-brightness luminaires, mercury street lighting will truly come of age.

THOMAS J. SEBURN:* It was a privilege to have had the opportunity to review and discuss this paper prepared by an author who has had so much experience on the subject.

In his discussion of the applications of mercury light sources, the author's premise is based upon the lighting intensities established in the American Standard Practice of Street and Highway Lighting. This is no doubt a properly conservative approach, even though these values are recognized by lighting engineers as being the minimum for the various conditions indicated. Many lighting engineers are

*Wheeler Reflector Co., Boston, Mass.

*Associate Director, Yale University, New Haven, Conn.

thinking of considerably higher values, and many installations are being made of three to five footcandles.

It is recognized in the American Standard Practice that heavy traffic conditions eliminate surface brightness. It is stated that "where seeing by silhouette is interrupted by conditions such as dense or turning traffic, lighting adequate for seeing objects by surface detail should be provided." This point is further amplified in the Appendix of the American Standard Practice where it states that "silhouette discernment predominates in discernment of distant objects." Under the traffic conditions now prevalent on many important arteries, the clear distance necessary for discernment of distant objects is not available.

It is recognized that the author touches on these points but it would be of considerable interest to have the application data more specifically recognize them. For example, in Fig. 4, which incidentally does not show too well for the 100-watt mercury lamp, it would be of material interest to have the 1000-watt lamp included. There is evidence that it would be materially more significant.

It is felt that it would be of real value to have the author's experience devoted to an analysis of the problem of higher intensity lighting and the relation of mercury light sources to that problem.

E. E. PARKS:* In determining the relative lamp efficiencies as shown in Fig. 2, I would like to ask Mr. Young if he has taken into consideration the ballast losses for mercury lamps and also whether or not he used the average lumen output throughout life for the mercury lamps as well as for the incandescent lamps.

About four years ago, we started what was for us, an extensive program of mercury street lighting. In order to determine the lumen output of mercury lamps to be used in making footcandle calculations, we asked the lamp companies for a rate of depreciation and a mortality curve for the H-400-EI lamp. Two manufacturers submitted such curves, but by looking at them, you would never know they were for the same lamp. However, using the average of the two, we arrived at a lumen output of 17,000 throughout the rated life of 6000 hours. It was my understanding that the actual depreciation had been determined in the laboratory for the first 3000 hours.

Subsequently, with the cooperation of the lamp companies, we started making tests on many six lamps all of which were taken from service after 5600, 6000 and 7000 hours. The depreciation curve which was made from these data was found to be a straight line from 2000 hours to 7000 hours. The actual readings we had for 3000, 5600 and 6000 hours, fell almost exactly on this line. The average per cent of initial lumen output for the best mercury lamps, after 1000 hours use and up to 7000 hours, was as follows:

Hours	Per Cent Initial Lumens
1000	93.5
2000	88.0
3000	84.0
5600	73.3
6000	71.3
7000	66.8

On the basis of these data, we estimated that to obtain an average lumen output of 17,000, we could use these lamps for 7500 hours, and set up group replacement schedules for all mercury lamps based on one year and eight months use. (Approximately 7350 hours.)

In approximately two years, we have group replaced over 3000 mercury lamps. During that time, individual failures have been at the rate of 10 per cent or less.

From this it is evident that both the depreciation and mortality curves based on our experience would differ materially from that in Fig. 3, in that the rate of depreciation is much greater and the rate of failure a little lower, at least up to 7000 hours. If there is no explanation for this discrepancy and the lamp companies are willing to make the tests we would be glad to remove lamps from service which could be used in getting additional information.

In discussing "Luminaire Operating Cost Comparisons," Mr. Young states that " a recent installation of the 175-watt 7000-lumen lamp compared with the 6000 lumen incandescent, shows the cost of the required effective lumens per 100 lineal feet of street at around 80 per cent for mercury compared with incandescent."

When we made a study of these two lamps, we arrived at an entirely different conclusion. We assumed the lumen output during useful life to be the same, but where used in a Type I luminaire on a 30-foot street with a 25-foot mounting height, we found the coefficient of utilization of the mercury to be .42 as against .52 for the incandescent. Consequently, to obtain the same amount of light on the street, 23 per cent more mercury luminaires would be required.

Lamp renewal costs are based on group replacement of mercury at 8000 hours and incandescent at 2000 hours. Labor for lamp replacement was figured at fifty cents each for both.

Our installed cost for the incandescent luminaire is $132 and for the mercury, $185.

Using the same rates for energy, fixed charges and lamp costs as did Mr. Young, our results show that the annual cost for lighting using mercury luminaires would be $55.65 as against $47.20 for the same amount of lighting using incandescent luminaires. A breakdown of these costs is shown in Table A.

Disregarding cost, the incandescent luminaire has two distinct advantages over the mercury. First, with no ballast in the circuit, the maintenance would undoubtedly be less; and second, having a higher beam candlepower, it is possible to obtain more uniformity of lighting on the street with the wide spacing generally used in residential lighting.
This reference, of course, applies only to Types I and II luminaires. For higher intensity lighting, particularly on wider streets, mercury is unquestionably superior.

My greatest criticism of mercury lamps is that they last

TABLE A — Comparative Annual Operating Cost.

Lamp Renewals			
Mercury	$\frac{10.50 + .50}{2} \times 1.23$	=	$ 6.76
Incandescent	$(1.05 + .50) \times 2$	=	3.10
Energy			
Mercury	$200W \times 4000 \times 1.23 \times 1.5c$	=	14.76
Incandescent	$405W \times 4000 \times 1.5c$	=	24.30
Fixed Charges			
Mercury	$185 \times 15\% \times 1.23$	=	34.13
Incandescent	$132 \times 15\%$	=	19.80
Totals			
Mercury	$55.65		
Incandescent	47.20		

*Manager, Lighting Dept., Nashville Electric Service Co., Nashville, Tenn.

too long. To see a good mercury installation, in which the lamps have deteriorated to only a small fraction of the initial output always makes me feel that it is a pity the lamp cannot be made to fail when it has reached the end of its useful life.

I wish to express my appreciation to Mr. Young for giving us the advantage of the information which he could have gained only from a great deal of experience and hard work.

W. S. TILL:* A few years ago John Young gave us an excellent paper entitled, "Electric Discharge Lamps in Street Lighting Service." He has now brought that paper up-to-date and added a wealth of valuable new material based largely on his own application experience.

In addition to the lamps mentioned in his tables, there are also the relatively new 425-watt and 6.6-ampere mercury and fluorescent mercury types. These are not yet used in large numbers but are gaining favor. The 425-watt H17 lamp types will operate economically from a 480-volt distribution system with simple choke-type ballasts and with no cold-weather starting problem. The 6.6-A lamps require no ballast as long as the circuit contains certain protective control elements.

Our tests indicate that the H1000 A15, operated at 700 watts instead of the normal 1000, generally is less efficient than the 700-watt A-H18 lamp, despite the ratings each carries in Table I. In that table, the 1000-watt A-15 is rated at 36,500 lumens when operated at 700 watts, whereas the 700-watt A-H18 lamp operated at 700 watts is rated at 36,000. The latter has been rerated to 36,500 lumens, and the B-H18 has been rerated to 34,500 lumens. These values are conservative according to tests.

Continuing improvements make it difficult to keep any mercury lamp data table up-to-date for very long. Mr. Young should not wait three years before presenting his next paper in this field.

H. S. NONNEMAN:** As everyone fully realizes, the author of this paper has had wide experience in the use of mercury vapor lamps for street lighting purposes, and, as a result, the entire electrical industry has benefited from his work.

However, the performance of mercury light sources gives one cause for concern when considering the light maintenance vs the life of such sources. Many utility companies, such as the one I represent, must maintain light sources at least at 20 per cent of rated light throughout the life of the lamp, and you can readily see that at best this means group replacement after not more than a year's burning operation.

The use of so-called improved-color light sources represents additional cost of operation, and has not been accepted as greatly as anticipated. In a survey recently completed by the E.E.I. Street Lighting Committee, a check of 57 companies, representing 23½ million electric customers, it was found that in 105,500 mercury luminaires in operation, only 5000 were improved-color.

Also of particular interest is the fact that in 1953, 35,500 mercury luminaires were in operation, while in 1956, 105,500 were reported, whereas fluorescent luminaires started with 400 in 1953, and the number in 1956 was 7,850. Therefore, the percentage increase in fluorescent was three times that of mercury in a like period.

This would indicate to me that perhaps a like study on fluorescent sources would contribute even more to street lighting practice today, since the use of fluorescent lighting will perhaps equal or even surpass the use of mercury luminaires in the next few years.

JOHN W. YOUNG:* The contributions by the several discussers are much appreciated. I assume that the various topics reflect the rising interest in the present and future fortunes of the mercury lamp, and comments and criticisms should result in advancing the sum total knowledge of satisfactory mercury lighting.

Mr. Toenjes, in commenting on the most economic service life of mercury lamps, asks whether 8000 hours average is typical. While it cannot be said that this is typical, it is evident that more users are making trials of, or thinking on the basis of two years burning period. Average life in service is considerably in excess of the manufacturers' rating, and users frequently quote 10,000- to 12,000-hours burning period for groups of lamps. Such results are included, incidentally, by Mr. Parks in his discussion, and Mr. Fisher quotes from his experience.

While lamp mortality experience tends toward more favorable rates, the burning period with respect to lumen maintenance requires more investigation and analysis. Mr. Parks has given an example of its solution. Aside from average or minimum lumen output, there are various considerations that influence the stretch-out of replacement periods. Where truck-and-time costs are low, it is possible to allow a higher rate of burnouts before replacement. The inconvenience of traffic interference sometimes influences the interval. Coordinating mercury with incandescent group replacement periods is also done. More discussion on the economic life of mercury lamps is needed, including an understanding of operating practices involved.

As to the point of optical control of phosphor-coated lamps in luminaires, it follows that luminaire designs will be available as, in fact, one or more are in use now. Mr. Toenjes' statement on the applicability of the phosphor lamp is quite adequate. Two points might be added: temperature limitations of phosphor coated bulbs in luminaires and compromises in luminaire light distributions. Some luminaire types now being used with clear lamps, may, however, yield highly satisfactory illumination results.

On the topic of color, Mr. Waldron's comments on phosphor-coated lamps are to be noted. In his experience, emphasis is placed on improved-color not only for business areas but all areas. A specific point is the comment attributed to the police of readier and more accurate identification of color of cars and license plate numbers under color lamps. Mr. Waldron's experience tends toward all-color mercury lamps for street lighting.

Mr. Fisher's comments place use of coated lamps on a cost basis, and not necessarily on color. The 400-watt "white" lamp, for example, on an annual cost basis stands very slightly above the clear mercury on a 6000- to 8000-hour burning period.

Regarding Mr. Wylie's comments, Fig. 2 pertains, of course, to lamp efficiencies only. No disparagement of the filament source is intended in its comparative position with mercury in the lamp efficiency range of the three prevailing sources. The high optical efficiency of the filament lamp in luminaires is well known, and as Mr. Wylie has pointed out, it is light on the pavement, or the effective lumens, that count. Where light generation of the mercury can be effec-

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**Dayton Power and Light Co., Dayton, Ohio.

*Author.

tively utilized, this lamp definitely has an advantage in economy compared with incandescent for many applications. Luminaire designs for the concentrated mercury source have been steadily improved and compare favorably with incandescent, in coefficient of utilization values among other properties of light distribution.

The cost comparison shown includes cost of light generation only, since the next step, application of utilization coefficients is subject to variations among layouts that may be ruling or selected for certain reasons by the engineer. Rather than showing selections as typical, the author chose to cite practical examples with certain lamp sizes from one user's experience.

As to the infrequent case in which energy rates may be very low, of the order of a few mils, the advantages of economy derived from using high efficiency lamps such as mercury, will be reduced. Conceivably, the smaller lamps might not be practical, but though the margin may be small, mercury may still be desired for other qualities. For those cases that have come to the author's attention, it is seldom that energy rates used in cost studies fall below one cent per kw-hour.

Conventional mercury vapor ballasts were considered on all sizes in the study. The substitution of presently available series reactors would show for the smaller sizes meaningful reductions in the dollar cost per one million lumen-hours.

Relatively substantial savings in mercury lamp applications will be forthcoming with the production of an overall luminaire assembly, a package proposition, as the unitized luminaire for multiple systems.

Among the topics covered by Mr. Elmer, space permits the following brief comment. The feature of mogul bases throughout the line of lamps has appealed to operating personnel and the slight saving in equipping the 100-watt lamp with the medium base hardly compensates for the confusion of having two styles to adapt to a luminaire. On another point, the mogul base is more suitable for the smaller phosphor-coated bulb shapes.

Consideration of the open reflector luminaire in the cost study was omitted since lamp sizes that might be used as open bulb lighting are limited. Obviously, enclosing-glassware luminaires capable of taking two or three sizes of lamps, including the smallest practical size that might be used in open equipment, offers flexibility in illumination designs, and ultimate savings in installation costs of equipment.

Mention of a luminaire embodying a diffuser-reflector principle of light distribution was made to note an innovation in a commercially available design, field results of which are being awaited by the industry as to its applicability to class of roadway, and the evaluation of low brightness properties.

While the qualifications of refractor luminaires cannot be stated in a few words, modern mercury types furnish illumination superior to those available in the past. Present designs embody high utilizations, approaching or equaling incandescent types, with excellent control of light for a given type of light distribution. Glare is minimized through types having larger glassware areas and when mounted at proper heights.

Mr. Seburn's comments are pertinent to the trend in higher footcandle intensities that traffic demands are making on night-time use of roadways. The larger mercury lamps are capable of economically furnishing higher lumen lighting of the order of three to five footcandles for business areas, and up to 10 footcandles if desired. Such consideration of the 1000-watt lamp as made in the luminaire cost study shows that the light generation unit cost is slightly less than that for the 700-watt lamp.

In reply to Mr. Parks' question, in the luminaire cost study, ballast losses were included with the lamp watts in figuring energy cost. The mean lumen value on a 6000-hour lamp life was used in the lumen-hour calculations. As to comparisons of light designs, equipment selection and installed costs are bound to vary among users. For the included 175-watt example, the cost of the mercury and incandescent in place differed but slightly. Pole spacing was fixed, and utilization values around 30 per cent for both types of lamps furnished the required intensity for the street. Respacing, to take advantage of a high utilization, such as .52 per cent for the incandescent lamp luminaire, would not be practical in this instance. However, under consideration for the same type of street, shortly after, was a mercury lamp luminaire with a derived coefficient of utilization of .48 per cent, which approaches that of a highly efficient incandescent type. The approach in this study was not necessarily to prove in a given lamp size simply as a counterpart to the incandescent, but to obtain, if possible, an upgrading of lamp sizes which for a user's local conditions show a gain for an overall mercury system.

Mr. Till has pointed to three situations in lamp operating usage and economy. Although acquainted with some of the technical considerations, the author has had no direct experience with these lamps. So far, as Mr. Till has stated, installations are limited. Field experience such as is available, will be welcomed and the results may be of real interest and value in the progress toward increased versatility in mercury lamp types and their operation.

Trends in lamp application, as shown in Mr. Nonneman's data, are of interest to the street lighting industry. Information from other sources confirms the rapidly accelerating rate of mercury lamp applications in street lighting service.

Applications for Retired Membership

By action of the membership of I.E.S., retired membership classifications are available to those members qualified. Privileges in these grades, earned by long membership in the Society, include reduced annual dues ($5.00) with the continued receipt of all Society mailings including ILLUMINATING ENGINEERING. Classifications are known as Member, Retired; Associate Member, Retired.

Those who are interested and qualified (at least thirty years of membership in the Society and 65 years of age) should communicate with the General Secretary at Society Headquarters, stating that they have retired from regular occupation in business or profession.

INSTALLATION AT CONNECTICUT LIGHT AND POWER CO. OFFICES, NORWALK, CONN.

Lighting a Reception Area

LIGHTING OBJECTIVE: To provide a high level of general illumination in a reception area of an office building.

GENERAL INFORMATION: This main entrance reception area is approximately 18 feet 9 inches by 26 feet 9 inches. The height from floor to plastic egg-crate louver ceiling is 9 feet 6 inches. Colors and reflectances of the major room surfaces are as follows:

ceiling plenum	white	82% RF	floor	gray	20% RF
walls	blue	50% RF	chairs	brown	12% RF
	mottled green	15% RF	desk	gray	10% RF

INSTALLATION: There are seventy 40-watt T-12 rapid start fluorescent lamps, four 30-watt T-8 and

(over)

A.I.A. File No. 31

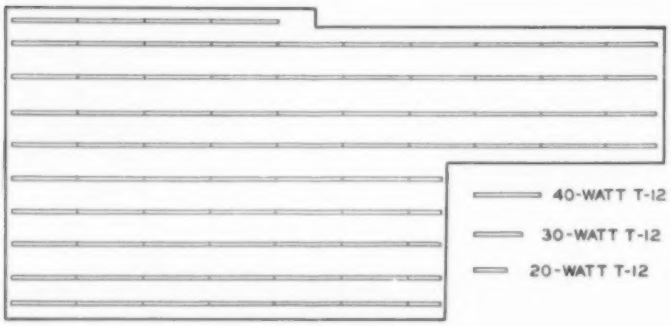

Figure 2. Plan view showing location of lamps above egg-crate ceiling.

five 20-watt T-12 trigger start fluorescent lamps (all standard cool white) mounted, as shown in Fig. 2, on 24-inch centers, 12 inches above the louver ceiling. The plastic ceiling (Fullerton Manufacturing Corp.) consists of translucent plastic egg-crate louver sections 47¾ inches by 10¾ inches, with ⅝-inch square cells providing 42- by 42-degree shielding. Unobtrusive plastic clips, matching the plastic louver, are used to line up the louvers and prevent one moving away from the other.

After approximately 3000 hours use, the average level of illumination was 90 footcandles. Brightnesses at that time were:

plastic ceiling			
at 45° lengthwise	110 fL	floor	15 fL
at 45° crosswise	120 fL	chair	6 fL
walls, blue	20 fL	desk	9 fL
mottled green	5 fL		

Lighting designed by Hill and Harrigan, 909 Whalley Ave., New Haven, Conn., and John Gage, Lighting Engineer, Connecticut Light and Power Co., Norwalk, Conn. Contractor: Bartoli Electric Co., Inc., 22 Knight St., Norwalk, Conn. Architect: Gilroy & Gaydosh, 64 Wall St., Norwalk, Conn.

Lighting data submitted by H. B. Adams, Design Engineer, Fullerton Mfg. Corp., Norwalk, Conn. division of Franklin Research Corp., as an illustration of good lighting practice and to aid in the design of similar installations.

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Estimating the Cost Of a Roadway Lighting System

By T. SUMMERS, JR.

IN DESIGNING a streetlighting installation there are many factors that must be considered. The desired illumination level can be provided by a multitude of luminaire, lamp and circuit combinations. Cost is always an important factor. In many cases the appearance of the installation justifies a more expensive installation than would be required if appearance were of no concern. Often times existing equipment will greatly influence (if not actually determine) what combination of equipment is to be used. This is especially true of the circuit to be used. However, if a completely new installation is to be made, including a new circuit used only for streetlight, then the advantages and disadvantages of each of the many types of circuits, light sources, and standards must be considered. It is the purpose of this paper to point out some of the advantages and disadvantages of the various types of circuits and the relative cost of different luminaire-lamp combinations when supplied by these circuits.

Types of Streetlighting Distribution Circuits

Series

One of the oldest methods of supplying electrical energy to streetlighting luminaires is by the use of a constant current system where all the lamps are placed in series. In order to maintain circuit continuity in case of a lamp failure, a film cut-out is placed across the lamp and this breaks down shorting out the lamp when it fails.

The equipment necessary for a series circuit is usually a moving coil constant current transformer which automatically adjusts itself to provide rated current in the series loop for all loads within its rated capacity; a primary remote-control oil switch; equipment to control the turn-on and turn-off time (time clock, photo control, etc.); and surge and short circuit protection. Other equipment that might also be used is a protective relay to cause the oil switch to operate and de-energize the circuit in case of an open circuit condition and power factor correction capacitors.

In order to reduce the extremely high voltage at the luminaire a series transformer can be used. With this arrangement the primary of the series transformer is connected in the series loop and the lamps are operated from the secondary of the transformer. The voltage at the luminaire is limited by an air gap in the transformer.

Until recently mercury lamps could not be operated from a series circuit without using a series mercury transformer. This transformer supplies the proper voltage to start the lamp and then limits the current once conduction has started. In order to operate mercury lamps without using series mercury transformers, circuits were developed to operate H1 mercury lamps from a 3.3-ampere series circuit and, as another approach, a 6.6-ampere mercury lamp was developed.

When mercury lamps are operated on a series circuit without the use of series mercury transformers, the equipment previously mentioned is necessary plus a potential transformer and a time delay relay. This additional equipment is required so that in case of a power dip or outage which extinguishes the lamps, the circuit will be de-energized for a sufficient length of time to permit the lamps to cool and then restrike in the normal manner. If this were not done, the lamps would try to restrike the arc and, being unable to do so, the film cutout would break down as in the case of a failed lamp.

The 3.3-ampere system requires a special constant current transformer but uses standard H1 mercury lamps. The 6.6-ampere system uses a conventional constant current transformer such as would be found in a local warehouse, but requires the H24 mercury lamp which has a 6.6-ampere lamp current.

Multiple

Another method of operating streetlighting luminaires is by the use of a multiple (constant potential) distribution circuit. In many cases, where the

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circuit is used solely to supply streetlighting equipment, the distribution transformer is loaded up to 125 per cent of its rated capacity. Often existing circuits supplying buildings, offices, etc., can be used and the luminaires can be operated from these existing circuits without the need of a separate system. The units can then be controlled by a pilot wire operating control relays or by the use of other similar schemes.

Where a separate circuit is used to supply the streetlighting equipment, the circuit may be identical to that used for supplying power to homes, offices, etc., except that a means of controlling the turn-on and turn-off time is required. This can be obtained by any number of methods but the most popular are by the use of a time-clock or photo control operating a primary oil switch.

Mercury and fluorescent lamps operated from a multiple circuit require a ballast in order to provide the proper voltage to start the lamp and then limit the current to the proper value once conduction has started.

Incandescent lamps are placed directly across a 120-volt line. Fig. 1 shows typical circuits and the components required.

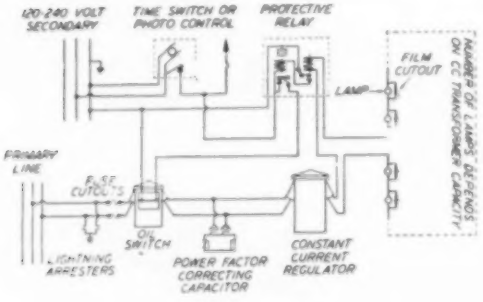
Advantages and Disadvantages Of Each Type of Circuit

The series circuit has the advantage that long runs can be made with a relatively small wire size. The main disadvantage is that extremely high voltages are present in the case of an open-circuit condition unless a series transformer is used, and this results in increased equipment costs. Another disadvantage is that "special" equipment such as constant current transformers are required.

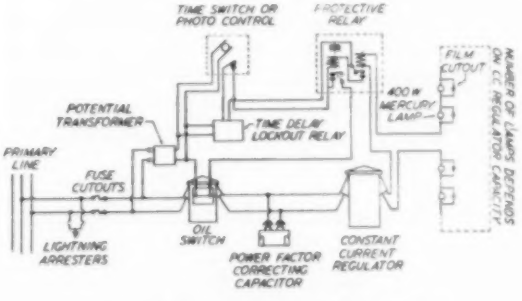
The multiple distribution circuit has the advantage of having a relatively low voltage at the luminaire and equipment is essentially the same as for the other distribution circuits. The main disadvantage for this system is that for large loads or long runs the cable size becomes excessive at the common voltages of 120/240. However, the increasingly popular 480-volt multiple system permits the serving of large loads or circuits of long runs with a relatively small wire size.

Constant Current Transformer and Distribution Transformer Loading

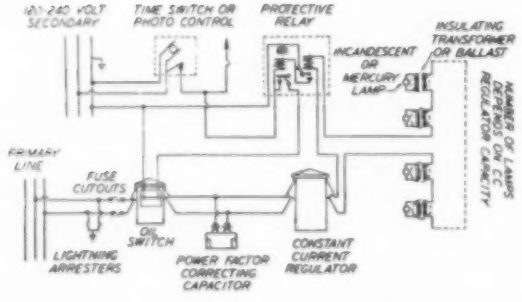
For most outdoor conditions, the voltage required to start a mercury or fluorescent lamp is



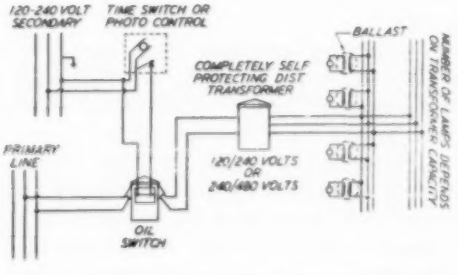
STRAIGHT SERIES STREETLIGHTING CIRCUIT FOR OPERATING INCANDESCENT LAMPS



STRAIGHT SERIES STREETLIGHTING CIRCUIT FOR OPERATING MERCURY LAMPS



SERIES STREETLIGHTING CIRCUIT WITH INSULATING TRANSFORMERS OR BALLASTS



MULTIPLE DISTRIBUTION STREETLIGHTING CIRCUIT FOR OPERATING MERCURY LAMPS

Figure 1. Typical streetlighting distribution circuits.

TABLE I — Recommended constant current transformer capacity per lamp.

	H1	H18	H15	Fluorescent
+20° F and above	800	1400	1900	890
0° F	900	1400	1900	940
−30° F	1000	1400	2100	1150

higher than its operating voltage. On a series circuit the available voltage of the regulator is divided among the ballasts on the circuit. Therefore, it is necessary to provide a specified amount of regulator capacity to insure the proper starting voltage. Higher voltages are required at low ambient temperatures and, therefore, more regulator capacity is required. The recommended amount of regulator capacity required for various lamps at ambient temperatures of +20°F and above, 0°F and −30°F is shown in Table I. When these allowances are made, there is usually additional regulator capacity available under operating conditions. Often this additional capacity can be utilized by serving some incandescent units with the same circuit as the mercury and/or the fluorescent units. The total load that can be handled in this manner will depend upon the watts and vars of all circuit components and the allowances for temperature and conditions of low primary distribution voltage.

In the case of mercury lamps operated from a straight series circuit the maximum number of lamps that can be operated from a given size regulator is determined by lamp operation in the case of the 3.3-ampere system and the number of lamps that can be started in the case of 6.6-ampere system. The maximum recommended number of lamps for the 6.6-ampere system is shown in Table II.

In the case of the multiple distribution system the total load on the transformer is calculated and then the required wire size must be computed. The wire size must be of sufficient size to maintain the proper voltage from the first lamp to the last lamp in the circuit. Any variation in voltage will affect the light output of the lamps. The allowable voltage drop will be determined by the type of ballast

TABLE II — Maximum number of H24 mercury lamps per circuit when supplied by overhead or underground distribution systems for various sizes of constant current transformers as temperature varies.

CC Transformer kw	Underground*			Overhead		
	−30° F	0° F	+30° F	−30° F	0° F	+30° F
10	12	12	13	9	10	11
15	18	18	20	14	15	17
20	23	24	26	19	21	22
25	29	30	33	24	26	28
30	35	37	40	29	31	34

*For non-magnetic sheathed cable buried directly in earth.

and the taps available in the case of mercury or fluorescent lamps or a maximum of 3 per cent in the case of incandescent lamps. When calculating transformer loading and wire size, it must be remembered to include the ballast losses and power factor.

There are many installations utilizing series circuits where the number of mercury lamps installed exceeds the recommended number. This has been done in order to effect economy in the number of regulators and associated equipment. There are circuits, especially in the southern part of the country, loaded as high as forty-five 400-watt E-H1 or J-H1 mercury lamps on a 30kw constant current transformer. These circuits are providing satisfactory service with no serious effects to date. However, it must be remembered that the recommended loading is on the basis of every lamp starting every time even under adverse conditions of temperature and primary voltage.

Although some savings can be realized by loading a regulator beyond the recommended value, these savings may be at the expense of more outages and possibly poor lumen maintenance and lowered light output. Depending upon the number of units on the circuit, if a Protective Relay is used, the current on starting may be enough below rated value and last for a sufficient length of time to cause the relay to operate resulting in the circuit being de-energized. If a Protective Relay is used on the circuit this will tend to limit the number of lamps on the circuit or a special relay will be required.

Cost Comparisons

In order to provide a true picture of the relative costs of different systems, a cost analysis should include not only labor and material costs for the original installation, but also all maintenance, operation and amortizing costs. Taxes, interest and insurance should be included when amortizing the cost of the installation.

As labor costs and local practices vary throughout the country it is impossible to make a cost comparison that is exact for all cases. However, a cost study can be made using an average of costs for various parts of the country and, while not being exact for any one particular locality or installation, will provide an indication as to the relative costs of the various systems studied. In the cost studies the actual mounting height is used rather than the "nominal" mounting height of 25 feet or 30 feet. As there is a difference in luminaire mounting height for transformer base on anchor base poles, this then results in a different coefficient of utiliza-

TABLE III — Cost of lighting analysis for one mile section of roadway, 60 ft curb to curb, underground distribution Streetlighting operated from its own distribution systems — no tie to

	LIGHTING SYSTEM NUMBER	6.6 AMPERES SERIES[1]					6.6 AMP. ST. SERIES[2]	
		I 34 Units/Cir	II 50 Units/Cir	III 32 Units/Cir	IV[4] 44 Units/Cir	V 32 Units/Cir	VI 52 Units/Cir	VII[5] 36 Units/Cir
DESCRIPTION OF LIGHTING SYSTEMS	1. Type of lamp (Fil., merc., fluor., etc.)	Filament	Filament	Mercury	Mercury	Fluorescent	Filament	Mercury
	2. Lamp description (Type)	15,000 L PS-52	10,000 L PS-40	E-H1	E-H1	F72T12/RS	10,000 L PS-40	A-H24
	(Watts per lamp only)	715	485	400	400	95	540	435
	3. Type of luminaire	Pendent	Pendent	Horizontal Mercury	Horizontal Mercury	Tilted Fluorescent	Pendent	Horizontal Mercury
	4. Number of lamps per luminaire	1	1	1	1	4	1	1
BASIC DATA	5. Rated initial lamp lumens per luminaire	15,000	10,000	21,000	21,000	23,400	10,000	20,000
	6. Lamp life	1,700	1,700	7,000	7,000	7,500	1,700	6,000
	7. Watts per luminaire (including auxiliary) + 10% line loss	825	583	484	484	481	594	473
	8. Coefficient of utilization	.398	.464	.516	.516	.281	.440	.499
	9. Maintenance factor	—	—	—	—	—	—	—
	10. Number of luminaires	160	206	88	88	144	216	96
	Spacing	66 Opp	51 Opp	120 Opp	120 Opp	73 Opp	49 Opp	111 Opp
	11. Average footcandles initial	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	12. Energy rate ($ per KWH)	$.01	$.01	$.01	$.01	$.01	$.01	$.01
	13. Estimated burning hours per year	4,000	4,000	4,000	4,000	4,000	4,000	4,000
INITIAL COST	14. Net luminaire cost (each)[6]	$ 275.—	231.—	243.—	243.—	439.—	167.—	173.—
	15. Net additional accessory cost per luminaire[7]	$ 73.—	53.—	88.—	71.—	79.—	63.—	95.—
	16. Estimated wiring & installation cost per luminaire	$ 104.—	97.—	124.—	124.—	110.—	85.—	110.—
	17. Net initial lamp cost each (list less 30%)	$ 2.10	1.75	14.00	14.00	2.63	1.74	19.25
	18. Net initial lamp cost per luminaire (4×17)	$ 2.10	1.75	14.00	14.00	10.52	1.74	19.25
	19. Total initial cost per luminaire (14+15+16+18)	$ 454.—	383.—	469.—	452.—	638.—	317.—	397.—
	20. TOTAL INITIAL COST (10×19)	$72,640.—	78,898.—	41,272.—	39,776.—	91,872.—	68,472.—	38,112.—
ANNUAL FIXED CHGS.	21. Initial cost per luminaire less lamps (14+15+16)	$ 452.—	381.—	455.—	438.—	628.—	315.—	378.—
	22. Total initial cost less lamps (10×21)	$72,320.—	78,486.—	40,040.—	38,544.—	90,432.—	68,040.—	36,288.—
	23. ANNUAL FIXED CHARGES (15% of 22)	$10,848.—	11,773.—	6,006.—	5,782.—	13,565.—	10,206.—	5,443.—
ANNUAL OPERATING COSTS	24. Annual no. lamp replacements (4×10×13÷6)	376	485	50	50	307	508	64
	25. Annual cost of replacement lamps (17×24)	$ 790.—	849.—	700.—	700.—	807.—	884.—	1,232.—
	26. Annual cost of replacement parts[8]	$ 723.—	785.—	400.—	385.—	904.—	680.—	363.—
	27. Total annual maintenance material cost (25+26)	$ 1,513.—	1,634.—	1,100.—	1,085.—	1,711.—	1,564.—	1,595.—
	28. Estimated labor cost to replace one lamp	$ 1.—	1.—	1.—	1.—	1.—	1.—	1.—
	29. Total labor costs to replace lamps (24×28)	$ 376.—	485.—	50.—	50.—	307.—	508.—	64.—
	30. Estimated cleaning cost per luminaire	$ 1.—	1.—	1.—	1.—	2.—	1.—	1.—
	31. Number of cleanings per year	2	2	2	2	2	2	2
	32. Annual cleaning cost (10×30×31)	$ 320.—	412.—	176.—	176.—	576.—	432.—	192.—
	33. Total annual maintenance labor cost (29+32)	$ 696.—	897.—	226.—	226.—	883.—	940.—	256.—
	34. Total Annual Maintenance Cost (27+33)	$ 2,209.—	2,531.—	1,326.—	1,311.—	2,594.—	2,504.—	1,851.—
	35. Annual Energy Cost (7×10×12×13÷1000)	$ 5,280.—	4,804.—	1,704.—	1,704.—	2,788.—	5,132.—	1,816.—
	36. TOTAL ANNUAL OPERATING COST (34+35)	$ 7,489.—	7,335.—	3,030.—	3,015.—	5,382.—	7,636.—	3,667.—
TOTAL & REL. COSTS	37. TOTAL ANNUAL COST (23+36)	$18,337.—	19,108.—	9,036.—	8,797.—	18,947.—	17,842.—	9,110.—
	38. Relative Annual Cost	213%	222%	105%	102%	220%	208%	106%
	39. Annual Cost per Footcandle (37÷11)	$ 6,112.—	6,369.—	3,012.—	2,932.—	6,316.—	5,947.—	3,037.—
	40. Relative Annual Cost per Footcandle	213%	222%	105%	102%	220%	208%	106%

[1] Using 30-kw regulators, #8 wire, and individual insulating transformers or ballasts.
[2] Using 30-kw regulators, #8 wire, no insulating transformers or ballasts.
[3] Loading based on the use of a completely self-protecting Class A transformer with taps, loaded up to 125% of rated capacity.
[4] Experimental loading — not generally recommended — no protective relay.
[5] This value for non-magnetic sheathed cable buried directly in earth.
[6] Luminaire + pole + ballast or insulating transformer.
[7] Wire + transformer or regulator + control equipment.
[8] One per cent of Total Initial Cost Less Lamps (Line 22).

system, steel poles, approximately 30 ft mounting height, designed to provide an average of 3.0 footcandles initial. existing secondary system. Minimum temperature at turn-on time, 0° F.

120/240 V[a]		240/480 VOLT[a]			480 VOLT[a]			480 VOLT[a]		
VIII	IX	X High React	XI Reg. Output	XII	XIII High React	XIV Reg. Output	XV Reactor	XVI High React	XVII Reactor	XVIII Reactor
Filament	Filament	Mercury	Mercury	Fluorescent	Mercury	Mercury	Mercury	Color Corrected Mercury		
15,000 L PS-52 800	10,000 L PS-40 575	E-H1 400	E-H1 400	F72T12/RS 95	E-H1 400	E-H1 400	A-H17 425	J-H1 400	B-H18 700	B-H15 1000
Pendent	Pendent	Horizontal Mercury	Horizontal Mercury	Tilted Fluorescent	Horizontal Mercury	Horizontal Mercury	Horizontal Mercury	Horizontal Mercury	Horizontal Mercury	Horizontal Mercury
1	1	1	1	4	1	1	1	1	1	1
15,000	10,000	21,000	21,000	23,400	21,000	21,000	21,000	20,000	34,000	52,000
1,350	1,350	7,000	7,000	7,500	7,000	7,000	7,000	7,000	7,000	7,000
880	632	505	512	504	505	510	495	505	809	1,144
.374	.440	.516	.516	.290	.516	.516	.516	.463	.404	.368
—	—	—	—	—	—	—	—	—	—	—
170	216	88	88	140	88	88	88	102	69	50
62 Opp	49 Opp	120 Opp	120 Opp	75 Opp	120 Opp	120 Opp	120 Opp	103 Opp	77 Stag	106 Stag
3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
$.01	$.01	$.01	$.01	$.01	$.01	$.01	$.01	$.01	$.01	$.01
4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
186.—	160.—	245.—	245.—	361.—	250.—	250.—	232.—	263.—	260.—	324.—
77.—	62.—	56.—	56.—	41.—	43.—	43.—	43.—	53.—	57.—	77.—
93.—	86.—	126.—	126.—	100.—	125.—	125.—	125.—	118.—	139.—	162.—
2.70	1.02	14.00	14.00	2.63	14.00	14.00	14.18	16.10	34.65	38.15
2.70	1.02	14.00	14.00	10.52	14.00	14.00	14.18	16.10	34.65	38.15
359.—	309.—	441.—	441.—	512.—	432.—	432.—	414.—	450.—	491.—	601.—
61,030.—	66,744.—	38,808.—	38,808.—	71,680.—	38,016.—	38,016.—	36,432.—	45,900.—	33,879.—	30,050.—
356.—	308.—	427.—	427.—	502.—	418.—	418.—	400.—	434.—	456.—	563.—
60,520.—	66,528.—	37,576.—	37,576.—	70,280.—	36,784.—	36,784.—	35,200.—	44,268.—	31,464.—	28,150.—
9,078.—	9,979.—	5,636.—	5,636.—	10,542.—	5,518.—	5,518.—	5,280.—	6,640.—	4,720.—	4,222.—
504	508	50	50	299	50	50	50	58	39	29
1,361.—	518.—	700.—	700.—	786.—	700.—	700.—	709.—	934.—	1,351.—	1,106.—
605.—	665.—	376.—	376.—	703.—	368.—	368.—	352.—	443.—	315.—	282.—
1,866.—	1,183.—	1,076.—	1,076.—	1,489.—	1,068.—	1,068.—	1,061.—	1,377.—	1,666.—	1,388.—
1.—	1.—	1.—	1.—	1.—	1.—	1.—	1.—	1.—	1.—	1.—
504.—	508.—	50.—	50.—	299.—	50.—	50.—	50.—	58.—	39.—	29.—
1.—	1.—	1.—	1.—	2.—	1.—	1.—	1.—	1.—	1.—	1.—
2	2	2	2	2	2	2	2	2	2	2
340.—	432.—	176.—	176.—	560.—	176.—	176.—	176.—	204.—	138.—	100.—
844.—	940.—	226.—	226.—	859.—	226.—	226.—	226.—	262.—	177.—	129.—
2,710.—	2,123.—	1,302.—	1,302.—	2,348.—	1,294.—	1,294.—	1,287.—	1,639.—	1,843.—	1,517.—
5,976.—	5,460.—	1,778.—	1,802.—	2,822.—	1,778.—	1,795.—	1,742.—	2,060.—	2,233.—	2,288.—
8,686.—	7,583.—	3,080.—	3,104.—	5,170.—	3,072.—	3,089.—	3,029.—	3,699.—	4,076.—	3,805.—
17,764.—	17,562.—	8,716.—	8,740.—	15,712.—	8,590.—	8,607.—	8,309.—	10,339.—	8,796.—	8,027.—
207%	204%	101%	102%	183%	100%	100%	97%	120%	102%	93%
5,921.—	5,854.—	2,905.—	2,913.—	5,237.—	2,863.—	2,869.—	2,770.—	3,446.—	2,932.—	2,676.—
207%	204%	101%	102%	183%	100%	100%	97%	120%	102%	93%

tion for any particular unit when using different types of standards.

Table III is a cost study showing a comparison of various types of luminaires and distribution systems designed to provide a high level of illumination such as is frequently being used in downtown business districts today. The systems utilizing color corrected mercury lamps are included to show the relative cost between the 400-watt clear and color corrected mercury lamps and also to provide an indication of relative cost in going to higher wattage lamps. As the 400-watt clear mercury lamp is a more familiar lamp than the color corrected or higher wattage lamps, this lamp was chosen as the mercury lamp to be used in all of the cost studies even though the trend is toward the use of color corrected lamps for new installations. As the 425-watt A-H17 high voltage lamp using a reactor ballast becomes unstable at approximately 90 per cent of rated lamp open circuit voltage it was not used as the 100 per cent base as this characteristic would eliminate it from consideration for many installations. The least expensive system (excluding the high voltage mercury lamp) is the E-H1 mercury lamp and high reactance ballast when served from a 480 V distribution system. This system was used as the 100 per cent base.

Table IV is a cost study showing comparisons of various luminaires when providing an illumination level such as is being used on many high density traffic roadways and secondary business streets.

Table V is a cost study of installations such as are being used on many expressway type roads. This study also shows a comparison between mounting the luminaires along the sides of the road or mounting them in the medial strip.

Breakdown of Costs

The form used for the cost studies is the one suggested by the *IES Lighting Handbook* (p. A-32). Most items are self-explanatory but Line 14 — Net Luminaire Cost (each), Line 15 — Net additional accessory cost per luminaire, and Line 16 — Estimated wiring and installation cost per luminaire, should be explained.

Line 14 — Net Luminaire Cost (each) includes the cost of the luminaire, the standard and the ballast or series transformer. Using as an example System I, Table III, the cost for this is as follows:

Luminaire	$ 73.76
Standard	135.74
6.6-20 amp. series transformer	65.45
Total	$274.95

Line 15 — Net additional Accessory Cost per Luminaire. This includes the cost of the wire, transformer and control equipment. Although the cost study is for a one-mile section of roadway, this figure was obtained on the basis of the total installation being much longer. A 30 kw Constant Current Transformer was loaded as indicated in the cost study and the cost for this one complete circuit was prorated among the number of units on the circuit to obtain the cost per luminaire. Again using System I of Table III the cost is obtained as follows:

30 kw "package type" self protecting C.C. Transformer	$1782.55
Hanger iron	12.65
Photo control	39.00
2700 ft #8 1/c 6000 V Direct buried cable	569.70
2400 ft #10 RWRH Wire	94.56
Total cost for the one circuit	$2498.46

$$\text{Cost per luminaire} = \frac{\$2498.46}{34} = \$73.00$$

Line 16 — Estimated wiring and installation cost per luminaire includes the labor costs for installing and connecting all equipment. Again this cost per luminaire was figured on the total cost of one circuit and then this cost was prorated among the number of luminaires on the circuit to obtain the cost per luminaire. Continuing using System I of Table III the cost is obtained as follows:

Install transformer base standard complete — $50.00 (each)	$1700.00
Install and connect luminaire — $7.00 (each)	238.00
Install and connect 6.6-20 ampere series transformer — $6.00 (each)	204.00
Install and connect package type self protecting c.c. transformer	110.00
Install and connect photo control	7.00
Install cable in pole and bracket — 1/c — $10.00 (each)	340.00
Install 100 ft Underground cable — 2 cables $42.00/100 ft (each)	42.00
Install 2200 ft Underground cable — 1 cable $40.00/100 ft (each)	880.00
Total Cost for the one circuit	$3521.00

$$\text{Cost per luminaire} = \frac{\$3521.00}{34} = \$104.00$$

The space available does not permit a complete list of all material and labor costs used. However, the above costs are typical of those used throughout the cost studies. It is not expected that the costs shown above agree exactly with the costs for any particular installation as explained previously. Although the costs above may be judged to be high or low in regard to a specific installation, the importance of these cost studies is not the actual costs (although this should not be a large difference when compared to a specific case) but in the relative costs. If the cost of an item is too low but is used in all cases, the relative cost will be unaffected. The same is true if a cost that is high is used.

TABLE IV — Cost of lighting analysis for one mile section of roadway 60 ft curb to curb, overhead distribution system, wood poles 30 ft mounting height, designed to provide an average of 2.0 footcandles initial. Streetlighting operated from its own distribution system — no tie to existing secondary system.

	LIGHTING SYSTEM NUMBER	120/240[1]		480 Volt[1]			240/480[1]
		I	II	III High React	IV Reactor	V High React	VI
DESCRIPTION OF LIGHTING SYSTEMS	1. Type of lamp (Fil., merc., fluor., etc.)	Filament	Filament	Mercury	Mercury	Color Corr. Mercury	Fluorescent
	2. Lamp description (Type)	15,000 L PS-52	10,000 L PS-40	E H1 400	A-H17 425	J-H1 400	F72T12/RS 95
	(Watts per lamp only)	800	575				
	3. Type of luminaire	Pendent	Pendent	Horizontal Mercury	Horizontal Mercury	Horizontal Mercury	Tilted Fluorescent
	4. Number of lamps per luminaire	One	One	One	One	One	Four
BASIC DATA	5. Rated initial lamp lumens per luminaire	15,000	10,000	21,000	21,000	20,000	23,400
	6. Lamp life	1,350	1,350	7,000	7,000	7,000	7,500
	7. Watts per luminaire (including auxiliary) + 10% line loss	880	632	505	495	505	504
	8. Coefficient of utilization	.378	.466	.503	.503	.453	.294
	9. Maintenance factor	—	—	—	—	—	—
	10. Number of luminaires	112	136	60	60	70	92
	Spacing	95 Opp	78 Opp	88 Stag	88 Stag	76 Stag	115 Opp
	11. Average footcandles initial	2.0	2.0	2.0	2.0	2.0	2.0
	12. Energy rate ($ per KWH)	$.01	.01	.01	.01	.01	.01
	13. Estimated burning hours per year	4,000	4,000	4,000	4,000	4,000	4,000
INITIAL COST	14. Net luminaire cost (each)[2]	$ 142.00	116.00	185.00	166.00	198.00	293.00
	15. Net additional accessory cost per luminaire[3]	$ 70.00	58.00	26.00	26.00	25.00	25.00
	16. Estimated wiring & installation cost per luminaire	$ 67.00	64.00	76.00	76.00	75.00	71.00
	17. Net initial lamp cost each (list less 30%)	$ 2.70	1.02	14.00	14.18	16.10	2.63
	18. Net initial lamp cost per luminaire (4×17)	$ 2.70	1.02	14.00	14.18	16.10	10.52
	19. Total initial cost per luminaire (14+15+16+18)	$ 282.00	239.00	301.00	282.00	314.00	400.00
	20. TOTAL INITIAL COST (10×19)	$31,584.00	32,504.00	18,060.00	16,920.00	21,980.00	36,800.00
ANNUAL FIXED CHGS.	21. Initial cost per luminaire less lamps (14+15+16)	$ 279.00	238.00	278.00	268.00	298.00	389.00
	22. Total initial cost less lamps (10×21)	$31,248.00	32,368.00	17,220.00	16,080.00	20,860.00	35,788.00
	23. ANNUAL FIXED CHARGES (15% of 22)	$ 4,687.00	4,855.00	2,583.00	2,412.00	3,129.00	5,368.00
ANNUAL OPERATING COSTS	24. Annual no. lamp replacements (4×10×13÷6)	332	403	34	34	40	196
	25. Annual cost of replacement lamps (17×24)	$ 896.00	411.00	476.00	482.00	644.00	515.00
	26. Annual cost of replacement parts[4]	$ 312.00	324.00	172.00	161.00	209.00	358.00
	27. Total annual maintenance material cost (25+26)	$ 1,208.00	735.00	648.00	643.00	853.00	873.00
	28. Estimated labor cost to replace one lamp	$ 1.00	1.00	1.00	1.00	1.00	1.00
	29. Total labor costs to replace lamps (24×28)	$ 332.00	403.00	34.00	34.00	40.00	196.00
	30. Estimated cleaning cost per luminaire	$ 1.00	1.00	1.00	1.00	1.00	2.00
	31. Number of cleanings per year	2	2	2	2	2	2
	32. Annual cleaning cost (10×30×31)	$ 224.00	272.00	120.00	120.00	140.00	368.00
	33. Total annual maintenance labor cost (29+32)	$ 556.00	675.00	154.00	154.00	180.00	564.00
	34. Total Annual Maintenance Cost (27+33)	$ 1,764.00	1,410.00	802.00	797.00	1,033.00	1,437.00
	35. Annual Energy Cost (7×10×12×13÷1000)	$ 3,942.00	3,438.00	1,212.00	1,188.00	1,414.00	1,855.00
	36. TOTAL ANNUAL OPERATING COST (34+35)	$ 5,706.00	4,848.00	2,014.00	1,985.00	2,447.00	3,292.00
TOTAL & REL. COSTS	37. TOTAL ANNUAL COST (23+36)	$10,393.00	9,703.00	4,597.00	4,397.00	5,576.00	8,660.00
	38. Relative Annual Cost	226%	211%	100%	96%	121%	188%
	39. Annual Cost per Footcandle (37÷11)	$ 5,196.00	4,852.00	2,298.00	2,198.00	2,788.00	4,330.00
	40. Relative Annual Cost per Footcandle	226%	211%	100%	96%	121%	188%

[1] Loading based on the use of a completely self protecting Class A transformer with taps, loaded up to 125% of rated capacity.
[2] Luminaire + pole + ballast.
[3] Wire + transformer + control equipment.
[4] One per cent of total initial cost less lamps (Line 22).

TABLE V — Cost of lighting analysis for one mile section of divided roadway, 30-20-30 ft, overhead distribution system, steel poles, approximately 30 ft mounting height, designed to provide an average of 2.0 footcandles initial, poles mounted 10 ft from edge of pavement. Streetlighting operated from its own distribution system — no tie to existing secondary system.

		Poles Mounted on Outside of Roadway			Poles Mounted in Medial Strip		
	LIGHTING SYSTEM NUMBER	I 120/240 V[1]	II 480 V[1]	III 240/480 V[1]	IV 120/240 V[1]	V 480 V[1]	VI 240/480 V[1]
DESCRIPTION OF LIGHTING SYSTEMS	1. Type of lamp (Fil., merc., fluor., etc.)	Filament	Mercury	Fluorescent	Filament	Mercury	Fluorescent
	2. Lamp description (Type)	10,000 L PS-40	E-H1	F72T12/RS	10,000 L PS-40	E-H1	F72T12/RS
	(Watts per lamp only)	575	400	95	575	400	95
	3. Type of luminaire	Pendent	Horizontal Mercury	Tilted Fluorescent	Pendent	Horizontal Mercury	Tilted Fluorescent
	4. Number of lamps per luminaire	One	One	Four	One	One	Four
BASIC DATA	5. Rated initial lamp lumens per luminaire	10,000	21,000	22,400	10,000	21,000	23,400
	6. Lamp life	1,350	7,000	7,500	1,350	7,000	7,500
	7. Watts per luminaire (including auxiliary) + 10% line loss	632	505	504	632	505	504
	8. Coefficient of utilization	.358	.413	.22	.304	.399	.22
	9. Maintenance factor	—	—	—	—	—	—
	10. Number of luminaires	176	72	124	208	76	124
	Spacing	60 Opp	72 Stag	85 Opp	51	139	85
	11. Average footcandles initial	2.0	2.0	2.0	2.0	2.0	2.0
	12. Energy rate ($ per KWH)	.01	.01	.01	.01	.01	.01
	13. Estimated burning hours per year	4,000	4,000	4,000	4,000	4,000	4,000
INITIAL COST	14. Net luminaire cost (each)[2]	$ 189.—	268.—	372.—	133.—	203.—	314.—
	15. Net additional accessory cost per luminaire[3]	$ 34.—	22.—	20.—	29.—	19.—	18.—
	16. Estimated wiring & installation cost per luminaire	$ 70.—	81.—	76.—	45.—	53.—	47.—
	17. Net initial lamp cost each (list less 30%)	$ 1.02	14.00	2.63	1.02	14.00	2.63
	18. Net initial lamp cost per luminaire (4 × 17)	$ 1.02	14.00	10.52	1.02	14.00	10.52
	19. Total initial cost per luminaire (14 + 15 + 16 + 18)	$ 294.—	385.—	478.—	208.—	289.—	390.—
	20. TOTAL INITIAL COST (10 × 19)	$51,744.—	27,720.—	59,272.—	43,264.—	21,964.—	48,360.—
ANNUAL FIXED CHGS.	21. Initial cost per luminaire less lamps (14 + 15 + 16)	$ 293.—	371.—	468.—	207.—	275.—	379.—
	22. Total initial cost less lamps (10 × 21)	$51,568.—	26,712.—	58,032.—	43,056.—	20,900.—	46,996.—
	23. ANNUAL FIXED CHARGES (15% of 22)	$ 7,735.—	4,007.—	8,705.—	6,458.—	3,135.—	7,049.—
ANNUAL OPERATING COSTS	24. Annual no. lamp replacements (4 × 10 × 13 ÷ 6)	521	41	264	616	43	264
	25. Annual cost of replacement lamps (17 × 24)	$ 531.—	574.—	692.—	628.—	602.—	694.—
	26. Annual cost of replacement parts[4]	$ 516.—	267.—	580.—	430.—	209.—	470.—
	27. Total annual maintenance material cost (25 + 26)	$ 1,047.—	841.—	1,272.—	1,058.—	811.—	1,164.—
	28. Estimated labor cost to replace one lamp	$ 1.—	1.—	1.—	1.—	1.—	1.—
	29. Total labor costs to replace lamps (24 × 28)	$ 521.—	41.—	264.—	616.—	43.—	264.—
	30. Estimated cleaning cost per luminaire	$ 1.—	1.—	2.—	1.—	1.—	2.—
	31. Number of cleanings per year	2	2	2	2	2	2
	32. Annual cleaning cost (10 × 30 × 31)	$ 352.—	144.—	496.—	416.—	152.—	496.—
	33. Total annual maintenance labor cost (29 + 32)	$ 873.—	185.—	760.—	1,032.—	195.—	760.—
	34. Total Annual Maintenance Cost (27 + 33)	$ 1,910.—	1,026.—	2,032.—	2,090.—	1,006.—	1,924.—
	35. Annual Energy Cost (7 × 10 × 12 × 13 ÷ 1000)	$ 4,449.—	1,454.—	2,500.—	5,258.—	1,535.—	2,500.—
	36. TOTAL ANNUAL OPERATING COST (34 + 35)	$ 6,359.—	2,480.—	4,532.—	7,348.—	2,541.—	4,424.—
TOTAL & REL. COSTS	37. TOTAL ANNUAL COST (23 + 36)	$14,094.—	6,487.—	13,237.—	13,806.—	5,676.—	11,473.—
	38. Relative Annual Cost	248%	114%	233%	243%	100%	202%
	39. Annual Cost per Footcandle (37 ÷ 11)	$ 7,047.—	3,244.—	6,618.—	6,903.—	2,838.—	5,736.—
	40. Relative Annual Cost per Footcandle	248%	114%	233%	243%	100%	202%

[1] Loading based on the use of a completely self protecting Class A transformer with taps, loaded up to 125% of rated capacity.
[2] Luminaire + pole + ballast.
[3] Wire + transformer + control equipment.
[4] One per cent of total initial cost less lamps (Line 22).

Conclusions

The cost study comparing incandescent, fluorescent and mercury luminaires when served by series or multiple circuits (Table III) shows that the type of distribution system will make little if any difference in either the initial or annual operating cost.

This can be expected for all cases except where very long runs are to be made such as residential or secondary traffic streets. In this case the series distribution system will tend to be more economical.

The use of wood poles and overhead wiring (Table IV) results in a considerable savings in the cost per luminaire. When the total annual cost is considered, however, the savings are not as great as might be expected. The savings show a range of only 20 per cent to 30 per cent depending upon the system being considered.

Although some economy can be realized by using twin bracket poles mounted in a medial strip, the savings are not as great as might at first be expected. (See Table V.) This is due almost entirely to the fact that more units are required as the coefficient of utilization is lower. This, then, means more equipment to purchase, install, operate and maintain. Also, the additional bracket tends to offset some of the difference. This is especially true in view of the fact that more luminaires are required.

Hence, the number of twin bracket poles for medial strip mounting is more than half the number of single bracket poles for mounting at the side of the road. While the Total Initial Cost is approximately 20 per cent to 25 per cent cheaper for the medial strip mounting systems, the annual cost is approximately the same for incandescent and only about 15 per cent cheaper for the mercury and fluorescent systems. It is felt by some authorities that mounting poles in the medial strip presents a much more dangerous situation than mounting them at the sides of the road. In view of this, the small savings made possible by the method may not be justified.

The cost of any particular installation will depend upon many factors and will vary greatly depending upon the specific conditions encountered for each installation. For the particular set of conditions for these cost studies the approximate cost for a system using underground wiring and steel poles is $400 per unit for incandescent, $550 per unit for fluorescent and $450 per unit for mercury. If wood poles and overhead wiring are used the cost per unit is approximately $250 for incandescent, $400 for fluorescent and $300 for mercury. To obtain more accurate costs for any given installation the cost studies, and their explanations presented here, should be followed through and the exact costs for the conditions involved substituted for the values shown. However, for most cases the figures given above will provide a fair approximation.

Although the incandescent systems have the lowest cost per unit, more units are required to provide a given illumination level than are required with mercury due to the lower lumen output and utilization. The systems with the fluorescent lamp, which is the most efficient light source today, also require more units than are required with mercury due to the low coefficient of utilization. When all factors are taken into consideration, a given illumination level can be obtained more economically by using mercury than by using incandescent or fluorescent units. As pointed out in the beginning, the least expesive method of obtaining a given illumination level is not always the most desirable method. Mercury, while being the least expensive method, detracts from the brilliance of colors predominantly in the red end of the spectrum. In many cases a more expensive installation will be justified from the standpoint of color rendition alone. Depending upon the color rendition desired, the new Silver White colored mercury or the fluorescent mercury lamps can be used to obtain better color rendition and still retain the inherent economy of the mercury source. Such factors as this, and many others from an appearance or aesthetic viewpoint, may have such a strong influence as to relegate cost to a position of secondary importance. These factors must be taken into account for each installation and, although they do not show up in a cost study, they may very definitely have a monetary value even though the exact amount can not be determined.

Acknowledgement

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DISCUSSION

R. H. CHASE:* I would like to ask the author why he made his comparison for an equal initial horizontal illumination level instead of an equal maintained level. The maintenance factor for each system studied would be different, so that equal maintained illumination levels are not being compared.

It might be assumed that the dirt factor for each type of luminaire would be equal but the lumen depreciation for each type of lamp would be different. If the mean lamp lumens for the operating position of the lamp were used instead of the initial lumens, and the number of incandescent lights remained the same, then it would require 28 per cent more mercury lights and 26 per cent more fluorescent lights per mile than shown in the calculations of this paper.

This may not change any of the author's conclusions but it will not make the incandescent light look as unfavorable as compared with the vapor sources.

It is interesting to hear a paper mention the 480-volt multiple supply for the mercury vapor lamp. We are proposing to use the 480-volt three-phase system to feed mercury lights on limited access highways where the location of supply points is limited. Three-phase four-wire 480/832-volt multigrounded wye circuits will be extended from street light to street light. The lights will be fed single phase by connecting a 400-500-volt regulator ballast from phase wire to neutral.

We will be feeding as many as 250 400-watt mercury lights from one supply point using this system.

With this system it is possible to reach out 2½ times as far as a single phase 480-volt system using the same size conductor.

This paper is well done. The pattern set in this analysis should help anyone making a cost study of a particular lighting job.

JOHN HEINRICH:** Mr. Summers' paper reflects a very thorough knowledge of his subject, and a great deal of labor in putting his data together in a very interesting study.

While we know from experience that some of Mr. Summers' figures, particularly labor costs and maintenance factors are low, they are relative and apply to all types of installations, and therefore would not change his comparative figures.

Local conditions would, of necessity, be a deciding influence in the final choice of any system, as is true of any study of this nature.

GEORGE E. KORTEN:† The author has selected a very timely subject. Included in the street lighting material submitted for the third edition of the *IES Lighting Handbook*, the following statement appears under the title "Choice of Illuminant":

> "Cost studies for a specific installation are required to determine which type of light source and which type of supply, series or multiple, has the over-all economic advantage."

The Edison Electric Institute Street Lighting Committee has just completed a report from their 1957 street lighting survey, and the following is quoted from this report:

> "In the three-year interval since the 1954 survey there has been a substantial increase in the acceptance of both mercury and fluorescent sources for street and highway lighting. The ratio of mercury to fluorescent in use is approximately 10 to 1. As might be expected, the fluorescent luminaire has made the largest relative gain since the last report."

The E.E.I. survey indicated that about 60 per cent of mercury vapor lamps in use for street lighting service were the 400-watt, 20,000-lumen type. It also indicated that more than 60 per cent of the fluorescent luminaires in service use four six-foot lamps.

The author should be congratulated for using lighting systems having an initial illumination of three footcandles in Table III and an initial illumination of two footcandles in Tables IV and V when he compiled information for this cost comparison.

There are 18 different lighting systems described in Table III and 11 of these suggested the use of mercury vapor lamps. I would like to ask the author if all of the mercury vapor lamps listed are now in actual operation on any street lighting system. Early in May of last year a list of mercury vapor lamps for street lighting service was submitted to the committee now revising the *IES Lighting Handbook*. This list did not include the A-H24 435-watt lamp listed in Column VII. The A-H17 425-watt lamp listed in Column XV and the B-H18 700-watt lamp listed in Column XVII were on the *Handbook* list, but at that time no mean lumen values throughout rated life were available for publication. Of course it is possible that since that time more information has become available on these lamps.

Five of the systems listed considered filament lamps. For the series systems the lamp life is given as 1700 hours and for the multiple systems 1350 hours. These figures are for the shorter-life filament street lighting lamps. Many operating companies are now using the longer-life filament lamps rated at 3000 hours for both series and multiple. The lamps are usually replaced on a 2000-hour operating schedule or twice a year using the group replacement plan, and the luminaires are cleaned at the same time. Many utilities feel that they save money by replacing lamps and cleaning the luminaires on this type of schedule.

The only fluorescent street lighting systems described are in Columns V and XII and these are the luminaires which use four six-foot 95-watt lamps. In the business district of Indianapolis there is a fluorescent street lighting installation which uses twelve six-foot lamps in each luminaire. This has been in operation approximately twenty months and there is a rumor that the merchants on State Street in Chicago are considering the use of similar luminaires for the lighting of that street. Apparently these luminaires are doing a good job and it is possible that an installation of this type should have been considered in this cost study.

I am sure that we have all heard about the use of power-groove fluorescent lamps for street lighting service.

At the 1956 Conference in Boston, we were told about the new very high output fluorescent lamps. While these were withdrawn from the market early this year, there is a rumor that they are being improved and will soon be available for street lighting service.

Does the author not feel that power groove and very high output fluorescent lamps should be included in any up-to-date cost study?

Just as a matter of record, during the past several years there were at least twice as many fluorescent luminaires as mercury luminaires installed in business districts and on main traffic streets in the Lower Peninsula of Michigan.

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**Kansas City Power & Light Co., Kansas City, Mo.
†Consumers Power Co., Jackson, Mich.

An article, in the May 1957 issue of *Street Engineering*, by G. G. Wheeler of the Northern States Power Co., presents data to show that since July 1954, 91 per cent of the ornamental street lighting luminaires installed by communities in the utility's territory use fluorescent lamps.

Fluorescent street lighting may cost a little more but it is certainly very popular in the Great Lakes area.

FRED E. MOESTA:* Mr. Summers has presented a concise and detailed summary of estimating costs for roadway lighting using a variety of illuminants and circuits. I am sure that his methods will prove invaluable as a guide for anyone who has the responsibility for determining lighting costs.

In the discussion of the types of circuits, the constant current transformer is described as "special" equipment and hence a disadvantage of series circuits. I would question this connotation of "special" applied to the constant current transformer since the large majority of street lights in the country are supplied by such transformers. I would like to ask the author to amplify his statement that loading a constant current transformer beyond the recommended values with mercury lamps may *possibly* produce poor lumen maintenance of the lamps.

The tabulations of cost analysis are based on specific, initial footcandle levels. A more realistic approach would have been to use maintained footcandles which would then take into account the variance in lumen maintenance of the several illuminants considered.

On line 6 of the tabulations, the lamp life figures indicate lamp replacement of incandescent at 85-90 per cent of rated life but replacement of mercury and fluorescent at 100 per cent of rated life. This is a definite advantage for mercury and fluorescent sources in comparison to incandescent. The individual analyst must be cognizant of the fact and satisfied that replacement of mercury and fluorescent lamps at 100 per cent life is a satisfactory operating procedure.

On line 7 of the tabulation the watts per luminaire include a 10 per cent line loss. This is not a valid assumption in as much as the higher wattage incandescent lamps are closer spaced, and consequently in the case of series circuits they would have lower line losses than the lower wattage mercury or fluorescent lamps. It would be better to actually calculate line losses associated with each illuminant and with each circuit.

In any individual cost analysis based on this method it would be logical to include the investment in system facilities required to supply kva at the primary of the constant current transformer or distribution transformer.

FRANK J. SCHMITT:** Mr. Summers has done a voluminous job in estimating the costs of a roadway lighting system. The cost estimates here submitted leave little if any room for dispute and, as pointed out by the author, are subject to variables in ways and costs of doing, dependent on local conditions as encountered.

The theoretical roadways here lighted left me with the feeling that the average level of illumination, somewhere between two and three footcandles, was an essential to the lighting of all roadways. I feel quite sure that this was far from the author's intent. I therefore feel that a note of reassurance must be injected into our comments relative to the many street lighting jobs in our communities yet to be done but competing with other municipal needs for a share of the tax dollar.

Setting par at three footcandles in one case (Table III) and two footcandles in the other two cases (Tables IV and V), and basing all comparisons on initial footcandle values makes a strong case for mercury lighting in all instances. I feel quite certain that everyone who has a job of lighting to do under these circumstances will turn to mercury or fluorescent sources.

However, since Mr. Summers used three footcandles as par and felt the need to express himself on behalf of incandescent sources, I suggest that we at least go on record as saying that such levels of illumination where incandescent lighting is demanded, or preferred if you wish, we might go back to some of our earlier methods of applying twin luminaire units if we are to avoid a picket fence appearance, as might be expected with pole spacings of 66 feet or 51 feet opposite as shown in Table III, Columns I and II, respectively.

Costs of this type of twin-unit job, though requiring fewer poles, would not vary much from the costs set up by the author in the incandescent categories. The resultant lighting job is judged from others installed in the past such as State Street in Albany, New York, where there is a fine job completed ten years ago, with twin-unit incandescents.

There is a question in my mind that Mr. Summers might have granted a higher coefficient of utilization for the incandescent sources which are available. He should also have specified 3000-hour lamps under Columns II, VIII and IX of Table III as well as under similar conditions in Tables IV and V.

Savings in lamp replacements, by use of long-life lamps, are of the utmost importance not only because of the upward trends in labor and truck costs, but probably more so because of the fewer service trips under increasingly difficult traffic conditions. After all, this is one of the best sales pitches for mercury and fluorescent lamps.

R. M. SWETLAND:* In this interesting discussion of roadway lighting costs, it is reassuring to note that the author recognizes valid influencing factors, other than average footcandles on the pavement, as having an important bearing on the selection of a specific roadway lighting system.

While the suggested "framework" of items in this comparative study appears quite adequte, we should like to advance a few thoughts and suggestions relative to the "fabric and upholstering" used; first of a broader nature and then a few comments more specifically related to the text.

General

1. Admittedly, "average footcandles on the roadway" has long been recognized, too long, as a valid basis for comparing roadway lighting systems. Of course, we can conveniently and accurately measure horizontal footcandles.

However, we *do not see* at night along any roadway primarily by *virtue of*, or in *direct proportion to*, average footcandle levels. This fact, also, is generally recognized, of late, and is being quite conclusively demonstrated in an ever-increasing number of instances. We can have equal footcandles along the pavement, but *not necessarily equal "seeing."*

Furthermore, isn't the public paying for a degree of *see-*

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*Outdoor Lighting Dept., General Electric Co., Hendersonville, N. C.

ing and *comfort*, rather than a mere quantity of light — footcandles?

Consequently, it appears that we need the courage of our rapidly-forming convictions, and proceed to conduct such economic studies on the basis of "equal seeing" rather than on "equal footcandles." It is firmly believed that sufficient data, both by visual appraisal and instrumentation, have accumulated in many quarters to justify and substantiate such a basis of *equivalent seeing*.

For instance, there is one outstanding demonstration of three types of roadway lighting equipment, in western North Carolina, enabling an instantaneous appraisal of visibility and seeing along the same roadway section under comparable-sized luminaire equipment of fluorescent, filament and mercury lighting. The record of approximately 1000 visitors (to date) indicates a "seeing" preference of nearly 70 per cent for the system having an elongated six-foot low-brightness of true color discrimination; although this system produces only about *one-half* the *footcandles* on the *pavement*, as compared to a concentrated higher candlepower source having distinct color distortion characteristics.

2. If we *do* use "average footcandles" as our comparative basis, should we not use "maintained footcandles" instead of initial footcandles, at least to the extent of factoring-in lamp lumen depreciation? By so doing, we properly recognize the long-known and published differences in lumen output throughout the life of these various sources.

Again, wouldn't we come closer to the true user benefits of average "in-service" illumination per dollar of cost?

3. As we prepare and analyze more of these economic roadway lighting studies, we are becoming quite convinced that the equipment manufacturer should properly stop at the point of initial equipment cost comparison; with perhaps the addition of only such *few* annual operating costs as lamps and energy, if these costs and discounts are accurately known.

The user, or operating agency, then may add all other installation, amortization and variable maintenance costs which are *valid for his specific area*, and for which he, alone, can supply the accurate figures. This method has proved satisfactory in numerous instances; and results, generally in a more accurate appraisal for any given project.

More Specific Comments

Only a few typical comments and suggestions will be outlined here, with some specific reference to Table III:

1. The author refers to a cost study form in the *IES Lighting Handbook*, page A-32. A check reveals that this IES form is obviously intended for *interior* lighting practice; with the items differing widely from those used by the author. However, it does advise a "*maintained* footcandle" basis.

2. On a 3-footcandle average basis (Table III) isn't it a bit unrealistic and uneconomical to include lighting systems which involve a 49-, 51-, and 62-foot linear and opposite pole spacing? If these specific light sources are to be included, twin-mounted luminaires would seem to be the advisable approach.

3. In calculating luminaire spacing, the mounting height is given, in the author's tabulation, but not the luminaire overhang distance. Was this influencing factor considered?

4. A check reveals that the full 21,000-lumen and 20,000-lumen *vertical* rating of the E-1 and J-1 400-watt mercury lamps were used in the Table III calculation.

However, these lamps are operated *horizontally* in the luminaires; which means approximately a seven per cent decrease in lumen output, compared to the vertical ratings, in a vast majority of operating conditions.

We detect *no* over-wattage *compensation* in the submitted data to assure such vertical lumen rating when lamps are operated horizontally.

5. The four-lamp fluorescent luminaire is listed as "tilted." What degree of tilt was used? This factor influences the effective light on the roadway, and thus, the spacing and relative economy.

6. Relative to the fluorescent luminaire, what ambient temperature was assumed in these calculations? This, too, has an appreciable bearing on the spacing and economy.

7. Power groove fluorescent lamps were not mentioned. These lamps are now being used in roadway lighting practice, and can be expected to improve over-all fluorescent economic performance.

8. The author assumes a 1 cent per kilowatt hour energy cost. Wouldn't 1.5 to 2.0 cents have been more realistic?

9. In the author's concluding paragraphs, there appears an *installed cost* range estimate of from $400 to $550 per pole for the various systems, involving steel poles and underground circuits. This hardly seems to be a "typical" cost. Installed costs, per pole, from $800 to $1200 are in evidence in all sections of the country, for such retail business area installations.

Consequently, with a commendable "framework" of items in such a cost study, a great deal of care, thought and experience is needed to "get our facts on straight"; and to develop such studies with the users' interest (*maximum visibility*, with comfort, per dollar) upper-most in mind.

C. E. WALDRON:* The difficulties and manifold problems of estimating the cost of a roadway lighting system are quite apparent to all of us from Mr. Summers' paper and the chance of arriving at an answer acceptable to all those engaged in street lighting work is remote indeed.

I am greatly impressed with the detail of figures which is presented with this paper. I know they represent a respectable amount of work by Mr. Summers, and I expect by others since I seem to recognize some from previous comparisons of mercury and incandescent street lighting.

I would commend the author on his assumption of two and three footcandles for such roadway lighting, even as he has defined them as initial footcandles. I could perhaps understand some of the comparisons better if they were related to maintained values, but this is a minor point here.

Specifically, I would like to refer to Table III, where both series circuits and various multiple systems are compared. There is of course some difference in operating practice for street lighting systems. However, I believe that the use of the individual lamp transformer on series circuits for new work is rapidly being replaced with 20-ampere series circuits for the large incandescent lamps and this should be considered in any comparison between high intensity filament and mercury or fluorescent street lighting. I believe also that in Tables II, III and IV rather undue advantage is given to mercury luminaires in the relative coefficient of utilization. With modern types of luminaires, either incandescent or mercury, there is little difference in C.U., with the result that we have only the practical difference of lamp lumens. I do not mean that this is the only effective or governing comparison. I do mean that there does not exist the rather wide difference in luminaire efficiency which seems to be indicated in Mr. Summers' tables where the

*Niagara Mohawk Power Co., Albany, N. Y.

mercury luminaire is credited with a C.U. of .516 and the incandescent luminaire with 15,000 lumen lamps at .374.

The use of an efficient incandescent luminaire in this comparison would show a decreased number of incandescent luminaires per mile — and omitting the unnecessary individual lamp transformer would give a more realistic cost comparison. I am sure that most installations of incandescent street lighting would use the group replacement lamp (3000-hour), although Mr. Summers refers only to the standard street lamp with nominal rating of 2000-hour life.

The mercury lamp for street lighting application has some real advantages over other sources for those who operate and maintain street lighting systems, and I am a little allergic to comparisons which seem to present exaggerated data. For example — with the relatively long life of the present mercury lamp and the good lumen maintenance throughout its rated life, we are able to show substantial savings in time, labor and transportation for lamp replacement. Rather than replace two lamps or more per socket per year it would most surely be better to have only one lamp per socket in 16 or 18 months — and perhaps with the 100- and 175-watt mercury lamp — one in two years.

It is not always so much that you save money — as it is that you provide better service and release manpower for other work.

This is far more meaningful to me than a trade of added investment in street lighting equipment for a saving in kwhrs.

HAROLD F. WALL:* Mr. Summers has given an interesting comparison of various types of lighting systems for three types of roadways. In his written article he avoids most controversies by stating that the comparisons are not of any particular installations. There are, however, a couple of items that are most controversial and which are not covered in any way, even by implication. First of all, luminaire maintenance reductions are ignored completely. Does this mean that the author assumes them to be equal for all types of luminaires? Secondly, the author does not mention lamp maintenance. Take, for example, his figures on mercury and incandescent lamps. He has designed all installations for an initial 2 or 3 footcandles average. The Code calls for the design of installations to meet minimum footcandle levels. Fig. A shows the lumen depreciation curves for series incandescent and multiple mercury lamps throughout life. Note that the average lumen output of the 15,000-lumen incandescent series lamp is nearly equal to that of the E-H1 mercury lamp over its life of 7000 hours. On this basis the number of incandescent lamps for the same light output would be approximately the same as the number of mercury lamps. If you consider minimum light output, more mercury lamps than series incandescent lamps will be required. The author's comments as to why he ignored this feature of Code requirements and the lumen maintenance of lamps would be extremely interesting.

*Public Lighting Commission, City of Detroit, Mich.

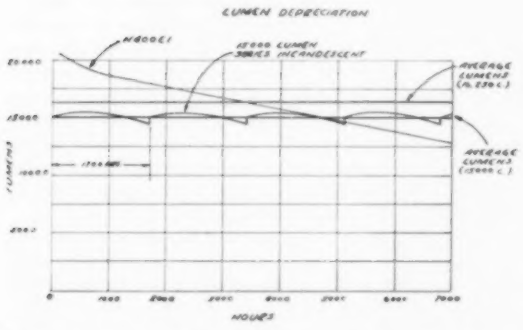


Figure A. Lumen depreciation curves for series incandescent and multiple mercury lamps throughout life.

HENRY L. WOJCIK:* The cost analysis by Mr. Summers is an interesting one even though, as he acknowledged, for any one lighting installation each of the cost items considered in the analyses will depend on many factors and conditions.

Current interest is in the Interstate System of Highways in accordance with the Federal Aid Highway Act. However, to provide a more complete cost study of a roadway lighting system, and a necessary one, the lighting of interchanges must also be considered in conjunction with the throughways, such as the 30-20-30 foot roadway used in the one analysis. Actually, the interchanges in the Interstate System, which can be many in the urban areas, will receive first consideration. The type of lighting system used for these interchanges may influence, to a large extent, the type of lighting system for the connecting throughways.

An interchange can be complex, what with 3 to 5 miles of slow and high speed one way (one- and two-lane) ramps (roadways), short and long ramps, acceleration and deceleration lanes, low overhead structures, etc. Thus, an interchange is not conducive to the use of maximum and/or ideal spacings, one type and size of light source, and one illumination level. In consequence the "Relative Annual Costs" in the cost analysis tables will be affected.

T. SUMMERS, JR.:** The author would like to thank the discussors for their comments and from the number of comments received (both verbal and written) I am sure the paper served its purpose in stimulating an interest and possible evaluation, and/or re-evaluation of the many different sources and circuits that are in common usage. One point that should be emphasized again is that the major comparison is intended to be on the basis of various circuits for a given type of source, and only secondary as a comparison of costs between the various sources. It would be virtually impossible to include all sources and circuits but it was attempted to include the best known combinations. The power groove, VHO, and SHO fluorescent lamps and the 12-lamp fluorescent luminaire were not included due to the limited number of installations using this equipment.

In answer to the comments of Mr. Chase, initial footcandles were chosen instead of maintained due to the many different maintenance programs and atmospheric conditions throughout the country. On this basis, incandescent sources do not appear as favorable as would be the case when maintained values are used, due to the good lumen maintenance of the incandescent lamps. However, when comparing different circuits for a given source this is immaterial.

Mr. Heinrich is certainly correct when he states that local conditions would be a deciding influence and it was attempted in the paper to point out this fact.

In answer to Mr. Korten's statement concerning the mer-

*Richardson, Gordon and Associates, Pittsburgh, Pa.
**Author.

cury lamps used in this paper, all of these lamps are in use by many different utilities. The A-H24 mercury lamp has been available for more than two years, and the H-17 lamps for more than three years. These lamps are listed in lamp publications.

It is true that many utilities are using the group replacement incandescent lamps rather than the random replacement lamps. This is an ever increasing trend with which most of us, I am sure, agree. However, practically all utilities are familiar with the random replacement lamp and many still use this lamp. Therefore, it was on the basis of being the most familiar lamp and a commonly used lamp that this choice was made.

The incandescent lamps were figured as being replaced at 90 per cent of their rated *laboratory* life, as the actual in-service life is less than the rated laboratory life. Mercury lamps and fluorescent lamps were figured as being replaced at 100 per cent of rated life as a group of these lamps will provide an average life in excess of rated life although the lumen depreciation will make it uneconomical to operate the lamps beyond rated life in most cases.

The term "special" was used in connection with the constant current transformer as it is not used for conventional distribution systems. Distribution transformers are required for normal usage and can be used either on distribution systems or street lighting systems, but a constant current transformer can be used only on a street lighting circuit. On this basis the term "special" was used in connection with the constant current transformer.

I agree with Mr. Moesta that line loss should not be taken as a flat 10 per cent but should be figured for each case. However, due to the many different practices followed by utilities throughout the country as to voltage drop and copper loading, this figure was chosen so that the change could be easily made and yet line losses would be included in the study.

Overloading a constant current transformer may cause poor lumen maintenance in the case of mercury lamps if the regulator is loaded to a point such that a permanent cathode hot spot is not readily formed.

Mr. Schmitt is correct in stating that two to three footcandles are not essential for all roadway lighting systems, and it was not intended to convey this impression. This would not be required except in the case of roadways where the traffic conditions or the advertising value justifies it. However, there are many existing and many planned installations where the illumination level is in this range or above. Twin luminaire units would be very desirable to eliminate or minimize the "picket fence" effect when the spacing is very small.

Mr. Swetland seems to feel that a cost analysis constitutes a recommendation which is far from the facts. A complete cost analysis may, and usually does, include several sets of conditions that are known to the engineer to be impractical but seem to illustrate the many solutions possible and leave it to the intelligence of the reader to arrive at a practical conclusion.

In answering his questions I will merely refer to his designation of them and not repeat them.

Under the general questions an additional phrase should be added. The statement would then be "We can have equal footcandles along the pavement but not necessarily equal seeing *because of glare*."

As for conducting economic studies on the basis of "equal seeing" rather than "equal footcandles," there has not been presented conclusive proof such that the Street Lighting Committee (of which he is a member) will agree to such a basis of comparison.

Also, the members of our Society engaged in research and education have not seen fit to make the claim that visibility is better under any one type of source for equal illumination levels. The color (or color rendition) of the source is immaterial. As for the comfort of the elongated six-foot low-brightness system of true color discrimination, actual calculations and the opinions of thousands of drivers agreed that this system produced more glare than two other systems to which it was compared. These systems were adjacent to one another and all conditions were identical except the illumination level which was lower for the system using the low-brightness source.

Many unbiased and trained observers believe that the "outstanding demonstration" in western North Carolina was designed to prove a point not supported by engineering facts.

As for including only initial equipment costs and annual lamp and energy costs, IES helped develop and has approved the form of presenting material used here.

1. and 2. Although the cost study form on page A-32 is set up specifically for interior lighting, this is because there would be much more use for it in this form. The actual value of these data being in the *Handbook* is to serve as a check, and to point out all items involved so they can be included. I disagree that the items differ widely. The terms shown are to make the information clear, concise, and complete, and can be used with very little change for a street lighting installation as well as an interior installation. The reasons for using intial rather than maintained illumination have already been discussed as has been the possibility of twin-mounted luminaires. Again Mr. Swetland is assuming that a cost analysis is a recommendation.

3 and 5. The luminaire overhang was considered in all cases and was 4 feet for Tables III and IV, and the luminaires were located over the edge of the pavement in the case of Table V where medial strip mounting was used. For the fluorescent luminaire, this was combined with the optimum angle of tilt to obtain the best performance.

4. The full rated output of the mercury lamps was used even though they were operated in a horizontal position, as compensated ballasts were used. This additional wattage is included in the analysis.

6 and 7. The comparisons were based on an ambient temperature of 78 F as is common practice. Although the light output increases at cooler temperatures, it decreases at higher temperatures. Power groove lamps were not included for the reasons given previously. Actually in the warmer sections of the country the power groove lamp will not provide much improvement to over-all fluorescent economic performance due to the lower luminaire efficiency and the reduced light output due to the relatively high ambient temperatures concerned. We have taken actual test data where the light output for a 4-lamp power groove luminaire installation was practically identical to the 4-lamp 1000 ma rapid start luminaire installation.

8. The rate of one cent per kwh is felt to be realistic when considering the rates throughout the country. This rate can vary from 4 mils to approximately 2.5 cents. On this basis one cent is a good average and permits anyone to correct to his own rate very easily.

9. The "installed costs" of from $400 to $550 per pole are felt to be typical for the conditions involved. We have

reports of lower, as well as higher costs. Actually, I will add to the statement of $800 to $1200 per pole, as we have information on costs as high as $1800 per pole.

In answer to the statements made in his last paragraph, many of the comments made above apply. However, when a form such as was used in this paper is followed where all the conditions and assumptions are clearly stated, we feel that the engineer can recognize the facts and arrive at the best solution for his specific set of conditions.

In answer to Mr. Waldron's comments, 20-ampere series circuits were not used in place of the 6.6-ampere circuits with insulating current transformers as it was desired to show the comparison between 6.6-ampere circuits with and without the use of the I.L. Transformers. In many cases the transformers are used from a safety standpoint in limiting the voltage at the luminaire to a low value. The 20-ampere circuit would have approximately ⅓ the voltage at the luminaire of the 6.6-ampere circuit, but even so it would be considerably above the value when the transformer is used.

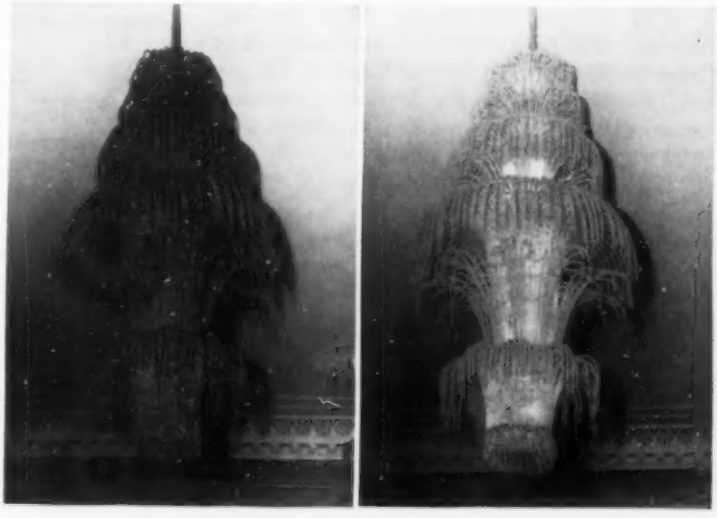
The coefficient of utilization used for the luminaires with incandescent lamps is typical for the distribution types used. The luminaire with the 15,000-lumen lamp provided a Type IV instead of a Type III light distribution, but this would normally be used under these conditions. The luminaire with a 10,000-lumen incandescent lamp provided a Type III distribution.

Some of Mr. Wall's questions have been answered above, but, to be more specific, luminaire maintenance factors were not ignored because they were assumed equal for all luminaires, but because the comparison was based on initial illumination levels for the previously mentioned reasons. Actually the maintenance factors for the luminaires will be practically the same for all units except those available with a sealed optical system. The lamp maintenance is entirely different as pointed out previously. Incandescent lamps have very good lumen maintenance, especially the series lamps. The average or *mean* lumen output of the 15,000-lumen incandescent lamp while approaching the average lumen output of the E-H1 mercury lamp is still less, approximately 13,250 lumens, compared to 16,300 lumens, or approximately 20 per cent. For a comparison of minimum light output the 15,000-lumen incandescent lamp is still less, approximately 12,750 lumens, compared to approximately 13,000 lumens. However, the usual practice is to use mean or 70 per cent of life lumens rather than minimum values and for these values the E-H1 lamp exceeds the 15,000-lumen incandescent lamp by significant amount.

As Mr. Wall stated, the Code calls for a minimum or "maintained" illumination level. The values used in this paper exceed these minimum values even when maintenance factors are taken into account. Therefore, the Code requirements were not ignored.

I agree wholeheartedly with Mr. Wojcik that in the case of expressways the interchanges must be considered in conjunction with the thruway portion. However, in order to do this an actual layout is a necessity, due to the many different possible arrangements of the interchanges. The locations of the interchanges would also be important. With many interchanges fairly close together, as might be the case with an expressway running through or close to a heavily traveled area, such as a downtown area, the influence of the interchanges would be much greater than where the interchanges are a considerable distance apart, as would be the case of an expressway through suburban areas. In a paper of this type, a cost comparison is for idealized conditions and shows both the practical and the impractical in order to provide a complete picture.

It appears that many of the people who reviewed this paper have interpreted the cost of light analysis to constitute a recommendation. I would like to emphasize that this is not the case; many of the combinations are impractical and undesirable, but they are included so as to be able to evaluate all possibilities. Conclusions reached from a cost analysis where all the assumptions and specific conditions are clearly indicated should be of greater value than a group of flat statements with no detailed explanations.



AFTER 30 YEARS without cleaning, the glass beads of this 500-pound chandelier were covered with grease, oil and dirt. Following two baths in a specially constructed 200-gallon tank with an anti-static solution, the beads again looked like new (far right). Since this chandelier is one of a set with 8 smaller ones and 24 wall brackets, all to be cleaned, the whole project was insured for $20,000 with Lloyds of London. The chandeliers are in the Grand Ballroom of the Women's Athletic Club, Chicago. ***Photo courtesy Merix Chemical Co.***

Recommended Light Characteristics Of Polystyrene Used in Illumination

Prepared by the IES-SPI-NEMA Subcommittee of the Light Control and Equipment Design Committee

Foreword

The use of plastic as an important function of light control is widely accepted in the lighting industry. Because of the acceptance and wide use there has been a continual demand for accurate correlation of data on the various plastics as a light control medium and also data on predicted maintenance and life. Several years ago, the activity of the Light Control and Equipment Design Committee was extended to investigate methods of providing members of the Illuminating Engineering Society with adequate information.

A subcommittee was formed composed of members of the I.E.S., the Society of the Plastics Industry, Inc., and the National Electrical Manufacturers Association. Early studies had determined that the problem was threefold: first, to establish measuring methods and terminology acceptable to both the lighting and plastics industry; second, to recommend light characteristics for various plastics so that correlation of measurable data would be made from materials conforming to basic recommendations; and third, to determine and correlate data applicable to the prediction of the behavior of plastics in lighting luminaires.

The material first chosen was polystyrene. This is to be followed by acrylics, vinyls and polyethylene. The first report, "Recommended Light Characteristics of Polystyrene Used in Illumination," has been completed and provides recommendations for the lighting industry to provide a material with predictable test results.

The primary responsibility of the I.E.S. representatives has been to furnish the leadership in covering the illuminating qualities, while the Society of Plastics Industry and the National Electrical Manufacturers Association groups developed suitable mechanical and physical characteristics.

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Approved by the Council of the Illuminating Engineering Society, February 1958. A Transaction of the I.E.S.

1. Scope

These recommendations for light characteristics serve to identify and to characterize thermoplastic polystyrene compounds for use, particularly in the manufacture of fluorescent light diffusing luminaires. Factors of fabricated luminaire design and performance are considered beyond the scope of this recommendation.

2. Types of Polystyrene

These recommendations cover the following three types of polystyrene compounds.

Class A — Unmodified polystyrene with or without the addition of diffusing pigments and small amounts of lubricants.

Class B — Essentially, Class A material characterized by improved heat distortion properties.

Class C — Essentially, polystyrene with or without the addition of diffusing pigments and incorporating additives to inhibit discoloration resulting from fluorescent light radiation.

3. General Requirements

In order to test check the lighting performance:

(a) The compound should be of uniform composition and so compounded as to conform to the requirements in these recommendations.

(b) Samples of the original color match should be submitted to the user for approval of color; and be representative of subsequent supply.

4. Detail Requirements

In order to insure that the test specimens shall be representative for checking illumination performance they should be injection molded under conditions recommended by the material supplier and should conform to the requirements in Table I.

TABLE I — Requirements of Test Specimens.

	ASTM Test Method*	Class A	Class B	Class C
Specific Gravity, min. (Method A)	D792	1.045	1.045	1.045
Tensile Strength, min., psi	D638	6,000	7,000	6,000
Elongation in 2 in., min., %	D638	1.0	1.0	1.0
Impact Strength, min., ft.-lbs./in. of notch	D256	0.25	0.25	0.25
Heat Distortion Temperature, Min., °F. ½ x ⅛ x 5 inch specimen, 264 psi fiber stress	D648	165	176	165
Burning Rate (in. per min., max.)	D635	2	2	2

*May be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa.

5. Sampling

The compound should be sampled in accordance with the sampling procedure described in the Methods of Testing Molding Powders used in Manufacturing Molded Electrical Insulators (ASTM Designation D392). A batch of compound should be considered as a unit of manufacture as prepared for shipment and may consist of a blend of two or more "production runs" of material.

6. Recommendations and Test Methods

The following are the recommendations and the test methods for determining the illumination characteristics:

(a) For those tests where conditioning is required, the molded test specimens should be conditioned in accordance with Procedure B of the Methods of Conditioning Plastics and Electrical Insulating Materials for Testing (ASTM Designation D618).

(b) *Test Conditions*—Tests should be conducted in the standard laboratory atmosphere of 23C ± 1.1C (73.4F ± 2F) and 50 ± 2 per cent relative humidity, unless otherwise specified in the testing methods.

(c) *Stability Toward Yellowing* —

(1) *Apparatus*—Fadeometer (Type FDA-R) carbon arc accelerated aging device operated in accordance with procedures recommended in ASTM Recommended Practice E42-56 T at a black-panel temperature of 120F and a Hardy-type spectrophotometer.

(2) *Specimen Preparation* — Specimens of 0.100 inch ±0.005 inch thickness should be prepared from material by injection or compression under conditions specified by the material supplier.

(3) *Determination of Stability Toward Yellowing* — Specimens should be exposed in the carbon arc device for a minimum of 100 hours for Class A and B and 500 hours for Class C. Specimens should then be examined for degree of yellowness with the spectrophotometer in accordance with Test for Luminous Reflectance and Color of Materials (ASTM Designation D791) and the following equation:

$$\text{Yellowing Factor} = 100\,\frac{(T_{420}-T'_{420})-(T_{680}-T'_{680})}{T_{560}}$$

where T_{420} = per cent transmission of same thickness of unexposed material at 420 mμ

T_{560} = per cent transmission of same thickness of unexposed material at 560 mμ

T_{680} = per cent transmission of same thickness of unexposed material at 680 mμ

T'_{420} = per cent transmission of specimen at 420 mμ

T'_{680} = per cent transmission of specimen at 680 mμ

(4) *Tolerable Yellowing* — Specimens tested as above should be considered objectionably yellow if a yellowing factor of 15 is exceeded.

(d) *Refractive Index* — Methods of Test for Index of Refraction of Transparent Organic Plastics (ASTM Designation D542). Specimens should have a refractive index of from 1.585 minimum to 1.600 maximum at 23C.

(e) *Regular Light Transmission* — Standard

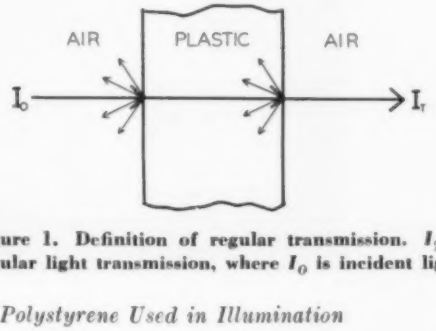


Figure 1. Definition of regular transmission. I_T is regular light transmission, where I_O is incident light.

Method of Test for Luminous Reflectance, Transmittance and Color of Materials (ASTM Designation D791), except that the specimen thickness shall be 0.100 inch ±0.005 inch. The regular light transmission of specimens should not vary more than ±3 per cent with pigmented compounds and ±2 per cent with unpigmented compounds. For a definition of Regular Transmission, see Fig. 1.

(f) *Reflectance* — Standard Method of Test for Luminous Reflectance, Transmittance and Color of Materials (ASTM Designation D791). The reflectance of specimens shall not vary more than ±3 per cent.

7. Number of Tests

One set of test specimens as prescribed in the methods of testing (Section 6) should be considered sufficient for testing. The average result for the specimens tested should conform to the recommendations in Section 6. All of the tests listed in Section 6, where applicable to the material, may be used to establish conformity of a material to these recommendations. It is recommended that routine inspection be limited to those tests required to identify the material to the satisfaction of the purchaser.

Appendix

Hiding Power — Hiding Power is defined as the degree of image obscuration. There is no accepted test method for determining this property at this time. However, there is continuous work by ASTM and other technical organizations to develop an acceptable method.

mil

Lighting for Landscaping

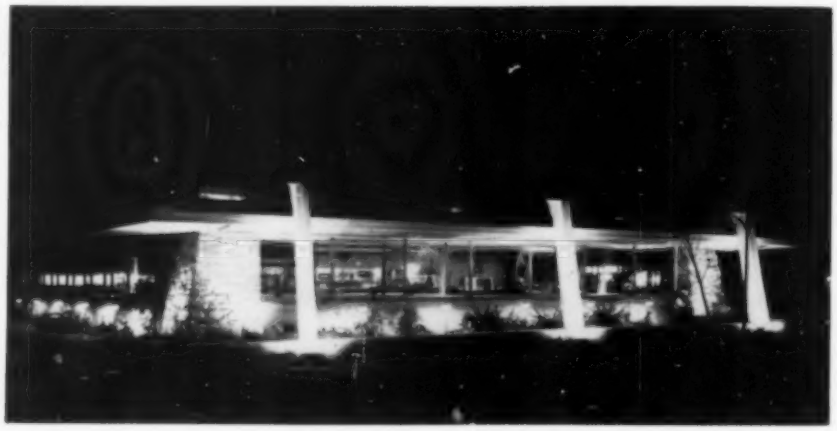
Lighting objective at Helsing's Restaurant was to highlight the exterior walls and landscaping without any resultant glare through the large glass windows at the front and sides of the building.

Experimentation on the blond brick wall areas showed that twelve 150-watt PAR38 floods aimed up at a 45-degree angle at the walls provided sufficient levels. An amber color was chosen for these lamps, to harmonize with the blond color of the brick.

For the landscaping under the windows, capped garden walk type units, using 100-watt yellow lamps, reflect all light down on plants and sidewalks.

On completion of the original objective by these methods, a further dramatic lighting technique was added. This was the floodlighting of the three exposed steel columns at the front of the building, to make them appear suspended in space. Two 300-watt narrow-beam PAR56 floods aimed at 90 degrees upward from the base of each column achieve this effect.

Lighting designed by Cecil R. Herren, Commercial Sales Representative, Arizona Public Service Co., Phoenix, Ariz. This installation won second prize in the Arizona Section's 1956 contest for My Most Interesting Lighting Job.



Views and Opinions

Should Pavement Brightness and Traffic Speed Enter Into Design of Roadway Lighting?

MANY STREET lighting authorities believe that modern streets and highways require increased levels of lighting because of increased traffic density and increased vehicular speeds. The American Standard Practice for Street and Highway Lighting has never included consideration of traffic speed in its recommendations of footcandle levels. For any future revision of the Practice, it would seem well to consider whether or not this consideration should be worked into the table of footcandle levels specified by the Practice.

Another segment of engineering thought believes that footcandle illumination does not provide a good criterion of street lighting visibility and that pavement brightness should be substituted as a superior criterion. In order to secure a consensus and to help crystallize the engineering approach to this problem, the following table has been proposed as a desirable revision of Table IV in the present American Standard Practice for Street and Highway Lighting.

In this table, two alternative criteria are presented, identified as Table IVa and Table IVb. Table IVa is a revision of what is substantially the present code but modified to take cognizance of varying traffic speeds. In order to forestall any questions as to actual traffic speeds in applying this rule, the table is based on posted speed limits rather than actual measured speeds.

Table IVb bridges the gap between the footcandle criterion and the pavement brightness criterion.

It is well known that the ultimate purpose of street lighting is not just to spread a layer of "footcandles" on the pavement, but to produce visibility on the streets and highways at night. Visibility is actually very loosely and indirectly coupled with footcandles. Visibility is obtained by creating brightness contrast between obstacles and the background. At the low levels of illumination commonly used in street lighting, the obstacle is usually dark and the background relatively bright. This means that pavement brightness is much more closely related to night-time visibility than footcandles.

The relation between footcandles of illumination

Suggested Revision of Table IV
American Standard Practice for Street and Highway Lighting

TABLE IV a — Recommended Illumination
Average Horizontal Footcandles (Lumens per square foot)

Traffic Density: Max. Vehicles per hour / Pedestrian Traffic		< 150			150-500			500-1200			1200-Up		
		L	M	H	L	M	H	L	M	H	L	M	H
Posted Speed Limits — MPH	15-25	0.1	0.2	0.4	0.2	0.4	0.6	0.4	0.6	0.8	0.6	0.8	1.0
	30-50	0.2	0.4	0.6	0.4	0.6	0.8	0.6	0.8	1.0	0.8	1.0	1.2
	55-Up	0.4	0.6	0.8	0.6	0.8	1.0	0.8	1.0	1.2	1.0	1.2	1.4

TABLE IV b — Recommended Pavement Brightness
Average Footlamberts 5 feet above horizontal, 200-foot distance

Traffic Density: Max. Vehicles per hour / Pedestrian Traffic		< 150			150-500			500-1200			1200-Up		
		L	M	H	L	M	H	L	M	H	L	M	H
Posted Speed Limits — MPH	15-25	.02	.04	.08	.04	.08	.12	.08	.12	.16	.12	.16	.20
	30-50	.04	.08	.12	.08	.12	.16	.12	.16	.20	.16	.20	.24
	55-Up	.08	.12	.16	.12	.16	.20	.16	.20	.24	.20	.24	.28

NOTE: Tables IV a and IV b are optional. Either table may be used as a standard of Street Lighting Performance.

and footlamberts of pavement brightness is indeterminate unless the vectorial (directional) value of the illumination is specified. In other words, pavement brightness is determined not by footcandles alone but by footcandles in a specified directional relationship to the observer. It is well known that a given illumination value in one certain direction will leave the pavement relatively dark, whereas the same footcandle level in another more favorable direction will produce strong pavement brightness.

In some of the newest roadway lighting equipment, such as the new directional type of luminaire which projects the bulk of the light toward the driver, the ratio of pavement brightness to total lamp-lumens is approximately doubled. This, of course, applies only to suitable applications on one-way streets and divided highways. The Practice was written long before this new equipment was introduced and is unfortunately quite unsuitable to use in applying these new lighting principles. For this reason, it is almost imperative that the footlambert brightness criterion be established in the immediate future.

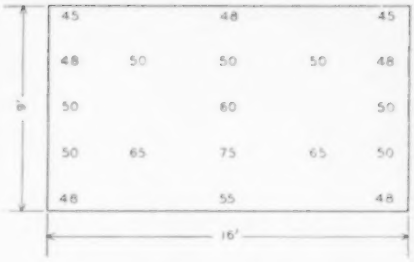
The suggested revision of Table IV would make the choice of criterion optional by the user of the Practice. In this way those progressive engineers who wish to use footlamberts could use the footlambert table, the conservative class could use the footcandle table. Judging by the trend in philosophy among street lighting engineers, it is most likely that the footcandle table would prove to be of decreasing usefulness and would eventually be dropped from the Practice. — W. B. ELMER, *Manager, Street Lighting Dept., Wheeler Reflector Co., 275 Congress St., Boston 10, Mass.*

Lighting for Estimating Electrical Bids

Blueprints are the usual visual task in the estimating room of Maxwell Electric Co., Spokane, Wash. The room is 15 x 15-feet in area, with ceiling height of 8 feet. Seven rows of 96-inch T12 and seven rows of 72-inch T12 fluorescent lamps are mounted on the ceiling in the 15-inch deep plenum. The corrugated vinyl ceiling is suspended on T-bar suspensions in 3-foot wide sections, each section providing entry on one side for lamp replacement and maintenance.

A maintained level of 60 footcandles is provided.

Lighting was designed by W. L. Haspedis, Columbia Electric and Mfg. Co., Spokane; Maxwell Electric Co. was contractor as well as customer. Entry was presented by Arne Rintala, lighting specialist, Washington Water Power Co., Spokane, in the Inland Empire Chapter's 1957 contest for My Most Interesting Lighting Job, where it won second prize.



Footcandle readings on face of sign.

INSTALLATION ON WILLIAM PENN HIGHWAY AT SANATOGA, PA.

Floodlighting a Sign

LIGHTING OBJECTIVE: To illuminate a highway advertising sign at dusk and night-time.

GENERAL INFORMATION: Black and red letters, painted on the white (81 to 86 per cent RF) background of this sign, advertise O. Wittenmeyer, T/A Sanatoga Radio Co. The sign's two faces are each 16 feet long and 9 feet high.

INSTALLATION: Four type L-108 General Electric Co. Fluorofiood enclosed luminaires, two 8-foot units per side, provide on the sign's faces the levels of illumination shown in the drawing. The luminaires are mounted 5 feet from the sign and on the ground, with the lamps at approximately the same height as the bottom of the sign face, as shown below. Each unit is provided with one 96-inch T-12 cool white high output fluorescent lamp. All four lamps are operated at 800 ma from two 2-lamp weatherproof ballasts (General Electric Co. catalog No. 89G646) located at the side of the sign.

On a clear night, with the illumination levels shown in the drawing, the sign is visible at approximately 1800 feet and legible at about 900 feet when approached from the west. When approached from the east, the sign is visible and legible at about 800 feet.

Lighting designed by George C. Linthicum, Philadelphia Electric Co., Phila., Pa.; Electrical contractor: William Werner, Pottstown, Pa.

Lighting data submitted by George C. Linthicum and George T. Anderson, Jr., Philadelphia Electric Co., Phila., Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

A.I.A. File No. 31-f

Here and There with I.E.S. Members

Judges and winners in the Arizona Section's contest for My Most Interesting Lighting Job, l. to r.: David Sholder, President, Central Arizona Chapter, American Institute of Architects, judge; William Kellogg, Class I winner; Andy Anderson, Class II winner; Glenn Baker, consulting engineer, judge.

Participants in the Milwaukee Section's contest for My Most Interesting Lighting Job, left to right, standing: T. Dustin, E. Schaefer, E. Klumb, W. Kuhnke, J. Burke, J. Lutz, C. Hart, M. Bruesewitz; kneeling: H. Olsen, G. Dolan, E. Schnoll. First prize winner in Class I, W. Kuhnke; and in Class II, J. Lutz. About 100 members and guests were present for the contest.

St. Maurice Valley Chapter on its annual industrial trip, this year visiting the Rest-Glo Manufacturing plant and the Molson Breweries, both in Montreal.

Ladies Committee for the National Technical Conference in Toronto, standing, l. to r., Mrs. J. C. Wilson (Chairman), Mrs. R. Lindsay, Mrs. G. F. Dean, Mrs. D. M. Jones; seated, Mrs. H. Wright, Mrs. J. W. Bateman, Mrs J. W. Nelson and Mrs. H. C. Jones. An extensive program is being planned.

LIGHTING NEWS

Attendance Analysis of the First National Lighting Exposition

Results of the National Lighting Exposition held at the Coliseum, New York City, March 9-12, would seem to dispel doubt, if any, that the industry needs, wants and will support by attendance, a trade show. The results, as summarized in an analysis just released by Harold Myer, President of National Lighting Expositions, show impressive statistics for attendance at this first exposition. A detailed breakdown of attendance, geographical and by industry occupation, may be obtained from him (550 Fifth Avenue, N.Y.C.).

Summarized, however, a total of 12,387 people were registered and attended the show, with a good spread of attendance over each day. This figure does not include women or others accompanying delegates; such attendees were not registered and not counted. Those attending were from 39 states, and 15 foreign countries. Business occupations of those attending the show break down as follows:

Electrical Contractors	1970
Electrical Wholesalers	2568
Electrical Engineering Firms	1464
Architects and Designers	1436
Decorators	750
Consultants	629
Builders	608
Education	264
Government	235
Manufacturers	897
Utilities	207
Purchasing Agents	181
Representatives of Foreign Countries and Purchasing Agents	112
Education	264
Miscellaneous	1066
	12,387

Exhibitors at the Exposition numbered 160 with 200 booths. Probably the majority of these were in the residential lighting field, but well displayed also were equipments for church, street, industrial areas, theatre, school, office, and a number of other interior and outdoor lighting fields. Not all of the Big Ten amongst the fixture manufacturers were represented in the exhibits, but those who were expressed satisfaction with the success of the show, according to Mr. Myer.

On the strength of the success of this first exposition, its managers plan another such trade show, probably expanded, for next spring. Tentative plans for this include the same site, New York City's Coliseum, special rooms for company meetings and an expanded symposium schedule.

This phase of the 1958 exposition, the Symposium, was especially valuable. It featured ten excellent lectures by unquestionable authorities in their respective subjects. The timeliness of the subjects and the caliber of the speakers attracted some 3000 people to the symposium alone. In detail, the schedule was:

Monday, March 10

R. G. Slauer, Sylvania Electric Products, Inc., Wheeling, W.Va. Subject: "Office Lighting."
George Nagel, Connecticut Dept. of Highways. Subject: "Street and Highway Lighting."
J. M. Chorlton, Superintendent of Maintenance and Construction, Toronto Board of Education. Subject: "School Lighting."

Tuesday, March 11

Thomas Smith Kelly, Lighting Consultant, New York, N. Y. Subject: "Background Lighting for Homes."
Prof. Stanley McCandless, Yale University. Subject: "Theatrical Lighting."
Peter Muller-Munk, Industrial Designer, Pittsburgh, Pa. Subject: "Lighting for Industry."
Kenneth C. Welch, Architect, Grand Rapids, Mich. Subject: "Lighting for Selling."

Wednesday, March 12

Abe H. Feder, Lighting Consultant, New York, N. Y. Subject: "Lighting for Public Recreation."
Walter Dorwin Teague, Industrial Designer, New York, N. Y. Subject: "Lighting Techniques for Public Institutions."
R. C. Allison, T. Eaton & Co., Toronto, Ont. Subject: "Use of Color and Lighting in Merchandising and Industry."

Sponsors of the exposition were the Lighting Lamps and Electrical Manufacturers' Salesman's Association.

Florida Section Repeats Outstanding Lighting Course

Bigger and better every year, the Advanced Lighting Course, sponsored jointly by the Florida Section of I.E.S. and the Tampa Electric Co., again outdid its previous successes. Attendance, both total (183) and average per session (112), was higher; number of "graduates" was greater; and general enthusiasm more contagious, with registration from eleven cities other than Tampa. On

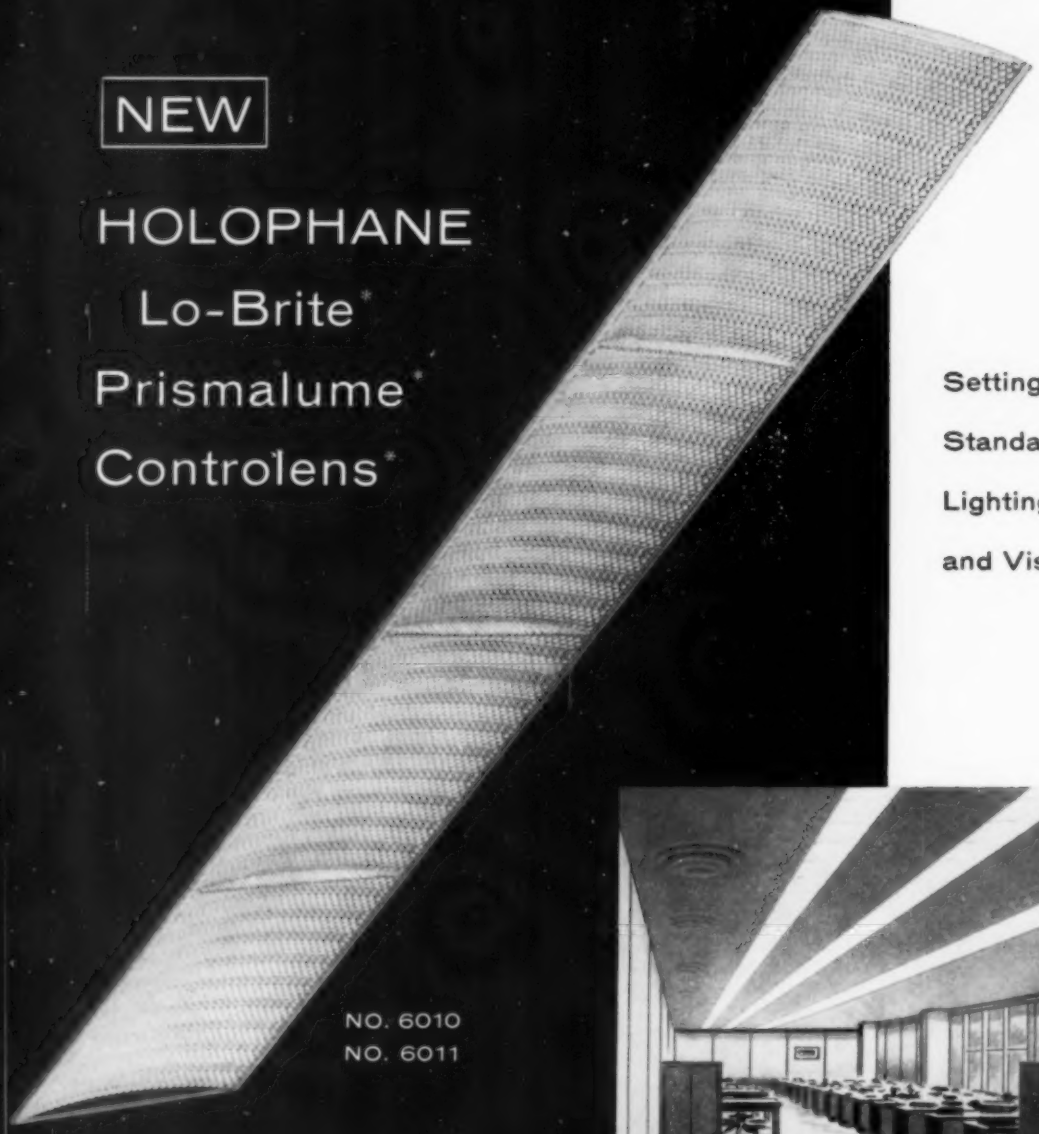
(*Continued on page* 11A)

ATTENDANCE averaged 112 per meeting at the six sessions of the Advanced Lighting Course, recently offered by the Florida Section of I.E.S. and the Lighting Department, Tampa Electric Co.

NEW

HOLOPHANE

Lo-Brite®
Prismalume®
Controlens®



Setting New High Standards of Lighting Efficiency and Visual Comfort

- One Piece— 4-Foot Length...
- Prismatic Acrylic Plastic...
- Unique Concave Shape...
- For 1-Foot-Wide Fluorescent Luminaires

This new 4-foot Holophane CONTROLENS offers advantages that are years ahead—that set it apart from ordinary diffusing elements... Made of crystal-clear acrylic plastic... light in weight ... free from discoloration... retains its shape... Its prismatic construction and concave contour assure exceptional lighting performance — directing maximum illumination to desired areas, minimizing brightness and glare... Modern and streamlined in design, it enhances the distinction of offices, banks, stores, showrooms — wherever the finest fluorescent lighting is indicated... Holophane lens distributors provide luminaires carrying these CONTROLENS. Specify 6010 for plaster and concealed T-Bar ceilings; 6011 for inverted grid ceilings.

For Better Lighting Holophane *...Be Specific*

Write today for engineering data and list of franchised lens distributors

HOLOPHANE COMPANY, INC.

Lighting Authorities Since 1898 • 342 MADISON AVENUE • NEW YORK 17, N. Y.

THE HOLOPHANE CO., LTD., 418 KIPLING AVE. SO., TORONTO 14, ONTARIO

W. C. McInnes, President of Tampa Electric, awards a certificate to a "graduate" of the Florida Section's Advanced Course. James A. Banton, Regional Vice-President, looks on.

(*Continued from page 9A*)

the closing night, 114 "diplomas" were awarded to the representatives of wholesalers, contractors, architectural firms, utilities and Local 108 of IBEW.

Schedule of topics and speakers at the six meetings was:

January 8 — Light Sources — M. L. Harkey.
January 22 — Lighting Design — Frank Moos.
February 5 — Store Lighting — J. A. Banton.
February 19 — Office Lighting — Herbert Nock.
March 5 — Industrial and Outdoor Lighting — E. B. Bradford.
March 19 — Residential Lighting — Claude Rollick, Charles Cockrell and Mrs. Jan Cave.

Following the course, unsigned questionnaires were returned, indicating overwhelmingly that those in attendance had benefited from the course and favored a similar one next year, with at least some sessions more advanced.

Cornhusker Section Again Holds Spring Lighting Conference

The annual Spring Lighting Conference of the Cornhusker Section of I.E.S. was held April 25, at the Sheraton Martin Hotel, Sioux City, Iowa. Following registration and luncheon the following program was presented:

Glare — Contrast Versus Safety — M. W. Getman, O.D.
Engineered Architectural Lighting — Jack Holzinger, Rambusch Decorating Co.
Heat and Balasts — Russ Viehman, Edwin F. Guth Co.
Hazardous Area Lighting — John E. Metzenthin, Crouse-Hinds Co.
New Ideas and Products for Outdoor Lighting — F. T. Tillemans, Westinghouse Electric Corp.

A social hour and banquet were held at the conclusion of the conference.

SCHEDULED EVENTS

May 22-24, 1958 — Pacific Northwest Regional Conference, Multnomah Hotel, Portland, Oregon.

June 4-5, 1958 — Council Meeting, I.E.S., New York, N. Y. Members are free to attend meetings of Council as guests.

June 9-13, 1958 — National Association of Electrical Distributors, 50th Annual Convention, Civic Auditorium, San Francisco, Calif.

June 23-24, 1958 — Great Lakes Regional Conference, Sheraton Hotel, Rochester, N. Y.

June 23-27, 1958 — American Institute of Electrical Engineers (Summer General Meeting), Buffalo, N. Y.

August 17-22, 1958 — Illuminating Engineering Society (National Technical Conference), Royal York Hotel, Toronto, Canada.

August 19-22, 1958 — American Institute of Electrical Engineers, Pacific General Meeting, Sacramento, Calif.

September 22-25, 1958 — Institute of Traffic Engineers (Annual Meeting), McAllister & Columbus Hotels, Miami, Florida.

October 8-10, 1958 — Canadian Electrical Manufacturers Association (14th Annual Meeting), Sheraton Brock Hotel, Niagara Falls, Canada.

October 10-11, 1958 — International Association of Electrical Inspectors (Canadian Section), Toronto, Ont.

October 13-14, 1958 — U. S. National Committee of the International Commission on Illumination (C.I.E.), Annual Meeting, Nittany Lion Inn, State College, Pa.

October 13-15, 1958 — National Electronics Conference, Inc., Hotel Sherman, Chicago, Ill.

October 19-24, 1958 — Society of Motion Picture and Television Engineers, Sheraton-Cadillac Hotel, Detroit, Mich.

October 20-24, 1958 — National Safety Council (46th National Safety Congress & Exposition), Chicago, Ill.

October 27-31, 1958 — American Institute of Electrical Engineers (Fall General Meeting), Pittsburgh, Pa.

November 10-14, 1958 — National Electrical Manufacturers Association (Annual Meeting), Traymore Hotel, Atlantic City, N. J.

November 18-20, 1958 — American Standards Association (9th Annual Conference on Standards), Hotel Roosevelt, New York, N. Y.

January 19-23, 1959 — American Institute of Electrical Engineers (Winter General Meeting), New York, N. Y.

March 1-4, 1959 — National Electric Sign Association, Morrison Hotel, Chicago, Ill.

March 30 - April 1, 1959 — Chicago Electrical Industry Show, Hotel Sherman, Chicago, Ill.

May 24-29, 1959 — National Association of Electrical Distributors (51st Annual Convention), Conrad Hilton Hotel, Chicago, Ill.

EEI Moves Offices

The general offices of the Edison Electric Institute were moved on April 25 from 420 Lexington Ave., New York to 750 Third Ave., New York. The headquarters had been in its former location since the organization of the Institute in 1933.

The move was made in order to house all departments and activities of the Institute on one floor for more economic and efficient administration. The telephone number, Lexington 2-3300, will remain the same.

Michigan Forum Booklet Describes Successful Conference

This year, the Michigan Section's Residence Lighting Forum not only ran a very successful Color, Light and Design Conference, but went one step further and told the story, through minutes of planning meetings, mailing pieces, synopses of the talks presented and photostatic evidence of the press coverage received from local newspapers, in a very attractive booklet.

This third annual Forum Conference, which was held last fall at the Detroit Edison Co. Auditorium, was designed particularly for interior decorators and co-sponsored by the Michigan Section of the American Institute of Decorators. The theme of the meeting was a "How-to-do-it-Circus" featuring luminous ceilings, use of pin point spots, picture lighting and garden lighting. Samuel M. Mills, an architectural engineer from General Electric Co., Nela Park, Cleveland, conducted the "Circus," giving installation data, construction facts, estimates of probable equipment and labor costs and other pertinent information.

Delegates were welcomed by Howard R. Stevenson of Detroit Edison Co., and heard a talk on the "Live Better Electrically with Adequate Housepower" program by Edward G. Edson, Detroit Edison Co.

C. Eugene Stephenson, Past-President and Chairman of the Board of A.I.D. and co-author of the book, *How To Decorate and Light Your Home*, gave the evening talk on "The Future of Decorating and

(*Continued on page 15A*)

Here are the reasons why...

Sylvania Fluorescents give you more light—

at lower cost than all other brands!

Superior engineering makes Sylvania fluorescent lamps better in many important ways . . . makes every lamp a better tool of production and sales to increase your profits.

TODAY, good lighting is more than illumination . . . it is a basic tool of production and sales. Sylvania, with this important premise always at work, offers business and industry a complete line of modern fluorescent lamps that assures efficient lighting . . . provides performance that means maximum service from your present fluorescent lighting system, and a higher return on your investment in the illumination of offices, factories or stores.

Why Sylvania lamps are best

It takes many things to make better fluorescent lamps. That's why ordinary fluorescents cannot match Sylvania lamps for light output, lamp life and dollar-for-dollar lighting value.

The reason? Sylvania builds many important major features into fluorescents . . . all contributing to superior lamp service and greater lighting economy.

Check these many points of superiority. See for yourself why you get more and save more. Notice, too, that Sylvania makes its most important comparisons with other brands . . . not with Sylvania products of the past.

Sylvania fluorescent lamps are as much as 14% brighter

Tests in the laboratory and working installations demonstrate that Sylvania lamps consistently deliver more light.

Equally important, during the past two years, an actual comparison of Sylvania fluorescent lamp performance with that of other brands shows Sylvania to deliver as much as 14% more light, depending on the lamp type.

Thus, you get the maximum light you expect . . . all the light you pay for . . . from the start.

Sylvania's greater maintained brightness means 7 lamps free for every hundred you use

Sylvania fluorescents maintain their greater brightness throughout useful life. For example, at 3,000 hours, in a single-shift operation, 100 Sylvania lamps deliver the light output of about 107 ordinary fluorescents. In effect, you get a dividend of light equal to 7 free lamps . . . more light-per-lamp from the power you pay for.

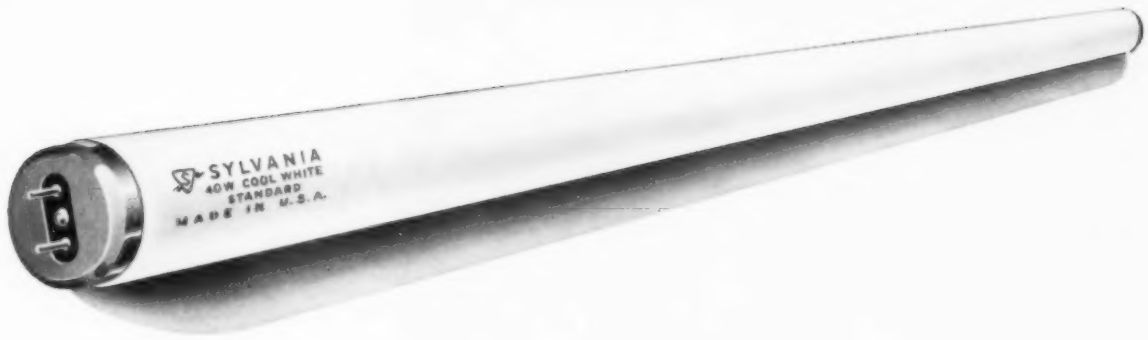
Sylvania welds all bases . . . eliminates faulty lamp contact

Sylvania welds the tube-to-base contact points in all its fluorescent lamps. Other brands use soldered contacts.

By welding, Sylvania completely eliminates the corrosion caused by soldering. Faulty lamp contact so common with ordinary fluorescents is eliminated. As a result, Sylvania fluorescents burn brighter far longer . . . save dollars and time in lamp maintenance.

Only Sylvania's exclusive coating process homogenizes phosphors for maximum brightness

Year after year, Sylvania lamps have delivered more light for a far longer time than ordinary fluorescents because of superior phosphors. In fact, only now are some other brands being introduced with phosphors of a quality which Sylvania has long since improved.



In addition, Sylvania uses an exclusive coating process which more uniformly distributes these superior phosphors throughout the tube. This unsurpassed uniformity is made possible by homogenizing the phosphors—and, in itself, contributes a minimum of 3% greater brightness over other processes now in use.

Sylvania lamps are 99.9% free of performance defects

Every lamp that leaves the plant is subjected to the infallible scrutiny of electronic devices that test and inspect for every possible flaw. One unit, for example, is so critical it can detect, in a fraction of a second, a lamp leak that would otherwise not become apparent until after many months of use. In this way you are assured of the highest lamp quality and performance.

Revolutionary VHO—first lamp to give 250% as much light as a standard tube

The Sylvania VHO (Very High Output) lamp represents a major breakthrough in fluorescent lighting. It produces 2½ times the light output without changing the size or shape of the tube.

The high intensity lighting "punch" of Sylvania's VHO offers new lighting levels that make it practical for the first time to gain the advantages of fluorescent lighting for High Bay installations, and for Outdoor illumination.

VHO lamps cost less to buy—less to use, and maintain greater brightness throughout life than other types of very high intensity fluorescents.

These facts are presented in the interest of demonstrating how better lighting is possible at a lower cost . . . how it contributes to increased production and working efficiency, and supports the many factors that reduce operating costs to improve profits.

We believe this concrete evidence of Sylvania's superiority in fluorescent lighting deserves the serious consideration of every executive or purchasing authority.

If you are planning new lighting, or are about to buy fluorescent lamps for your present system, let us demonstrate why you cannot afford to buy anything but Sylvania Fluorescent Lamps. Call or write us today.

Signed, Frank J. Healy

F. J. HEALY, President

SYLVANIA Lighting Products

A Division of SYLVANIA ELECTRIC PRODUCTS INC.

In Canada: Sylvania Electric (Canada) Ltd., Shell Tower Building, Montreal

Dept. 8L-3505, 60 Boston Street, Salem, Massachusetts

PERFECT VISION
for commercial fluorescent applications

when you think of **lighting**

think of **SMOOT-HOLMAN**

PERFECT VISION Luminaires combine attractive styling with even light distribution and high efficiency . . . easier hanging and lamping. The design has been copied, but not the lighting performance. Insist on the genuine, original PERFECT VISION Luminaire. Be sure it carries the SMOOT-HOLMAN label!

Write for brochure with performance data

SMOOT-HOLMAN COMPANY, *Inglewood, California*

Certified Lighting

(*Continued from page 11A*)

Lighting in the Home."

Displays of new equipment were on view throughout the sessions.

Attendance at this very successful decorator-oriented conference, planned under the leadership of Lloyd Gabler, Forum Chairman, and Belva Sanford, Chairman, Michigan Section A.I.D., was 155. Previous Forum Conferences have been designed especially for students and electrical contractors.

Solar House Opened For Public Inspection

A five-room house, heated and cooled entirely by a solar energy system, was opened April 10 for public inspection near Phoenix, Ariz. The system also supplies a year-round supply of hot water for the house and warms the water in the outdoor swimming pool. It consists of an underground water storage tank and a series of 86 louvers over the north and south patios and the central courtyard. Water heated by rays of the sun circulates through the louvers and flows into the storage tank.

The house is built from plans which won the first prize in last year's international architectural competition conducted by the Association for Applied Solar Energy. Designer is Peter R. Lee, a senior student in the School of Architecture, University of Minnesota. Mr. Lee is also associated with the firm of Bliss and Campbell, Minneapolis.

SMPTE Wins Oscar

In a ceremony not seen by the television audience because of limited air time, the Society of Motion Picture and Television Engineers received an Academy Award at the April 26 ceremonies. The Oscar was presented by film star Bette Davis to Barton Kreuzer of R.C.A., president of the society. The citation included with the Oscar read: "To the Society of Motion Picture and Television Engineers for forty years of continuing effort in standardization of engineering of motion pictures and dissemination of information to the film industry."

Council Meeting — June 4-5

Members of I.E.S. are invited to attend any meetings of the Council as guests, or to submit a communication for consideration on any matter through their Regional Vice-President or the General Secretary. The last Council meeting of this year is scheduled for June 4 and 5 in New York City.

CHARTER for Coastal Bend Chapter is presented to A. N. Saxon, right, Chairman, and B. L. Guess, center, Honorary life chairman, by Past Regional Vice-President John G. Felton.

Coastal Bend Chapter Has Charter Night

Charter presentation to the newly formed Coastal Bend Chapter of I.E.S. was celebrated February 13 in Corpus Christi, Texas. John G. Felton, past Regional Vice-President did the honors. Officers were installed by William G. Darley, Chairman of the parent Alamo Section.

The Chapter has evolved from the Corpus Christi Study Club, which was organized in February 1949 under the leadership of B. L. Guess, Chairman. A feature of the Charter Night ceremony was the presentation to Mr. Guess of a lifetime Honorary Chairman award.

Elmer Prag Scholarship Established at U. of Oklahoma

The Central Oklahoma Chapter of I.E.S. has established a scholarship at the School of Architecture, University of Oklahoma, in honor of the late Elmer Prag, charter Chairman of the group in 1955. Purpose of the scholarship is to help a student of demonstrated ability complete his architectural education, to stimulate more interest in lighting as an integrated architectural element, and to promote a closer relationship between I.E.S. and architectural students and faculty.

This scholarship of $100, contributed by the members of the Central Oklahoma Chapter, will be awarded at the end of each spring semester, the first presentation being made this May. Recipient will be chosen by vote of the entire architectural faculty, with the Chairman of the I.E.S. Student Activity Committee an ex-officio member of the board. The recipient shall have completed his sophomore year by the end of the spring semester in which he is chosen, and will be expected to reveal professional promise in the field of architecture.

Annual Maritime Conference Set for June 6-7

Attendance of over 200 is expected at the two-day conference of the Maritime Chapter of I.E.S., scheduled for June 6 and 7 at the Fort Cumberland Hotel, Amherst, N. S. Registration will begin on the evening of June 5.

A varied program of technical sessions and entertainment is planned by the committees under Conference Coordinator G. C. Robinson, Saint John, N. B. Special guests will include President Kirk M. Reid and Mrs. Reid; Regional Vice-President J. C. Wilson and Mrs. Wilson; I.E.S. Executive Secretary A. D. Hinckley, and I.E. Editor Ruby Redford. Members from other sections of Canada are also attending.

Electrical Contacts Seminar Scheduled at Penn State

A seminar, planned to be of particular interest to practicing engineers, physicists and research scientists working in the areas of heavy current and sliding electrical contacts, will be held June 16-18 at The Pennsylvania State University.

This annual three-day seminar on elec-

(*Continued on page 19A*)

He's carrying 144 square feet of beautiful ceiling

Luminous ceilings are easy to install, to take care of, and to see by. They can transform a room—any room, any size.

The key to their success is the use of BAKELITE Brand Rigid Vinyl Sheets. The sheets are so light in weight that one man easily carries 144 sq. ft. They are highly resistant to discoloration. They diffuse the light evenly throughout the room . . . no glare or harsh shadows.

Get all the facts on luminous ceilings made with BAKELITE Brand Rigid Vinyl Sheets. Write Dept. CP-82, Bakelite Company, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

It pays to design with BAKELITE BRAND PLASTICS

UNION CARBIDE

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KOOL KOIL

FABULOUS NEW ADVANCE FLUORESCENT LAMP BALLAST...

guaranteed to operate 15 to 20 degrees cooler

up to 15% more light output . . . increases ballast life 3½ to 4 times

eliminates use of costly radiators

HERE'S THE PROOF—

ADVANCE TRANSFORMER CO. • 2950 NORTH WESTERN AVENUE • CHICAGO 18, ILLINOIS

Here's the KOOL KOIL PROOF

AVERAGE TEST DATA* IN 40 C. CBM AND UL HEAT BOX

BALLAST TESTED	MAXIMUM COIL TEMP. °C	MAXIMUM CASE TEMP. °C	WATTS LOSS	LAMPS WATTS (147 Standard)	PERCENTAGE OF LIGHT OUTPUT
ADVANCE CAT. NO. RSH-2E75-S	89°	74°	23	145	97.0
Ballast "A"	108.5°	86°	26.5	139	93.2
Ballast "B"	105°	87°	28.5	137	89.8

AVERAGE TEST DATA* — REPRESENTATIVE FIXTURES

METAL SIDES AND PLASTIC DIFFUSER — 4-LAMP SURFACE MOUNTED

ADVANCE CAT. NO. RSH-2E75-S	100.5°	87°	23.5	122.5	82.2
Ballast "A"	124°	103°	25	111.0	74.5
Ballast "B"	117°	102°	27	108.0	72.5

DROPPED PLASTIC SIDES — GLASS BOTTOM — 4-LAMP SURFACE MOUNTED

ADVANCE CAT. NO. RSH-2E75-S	102°	89°	24	118	79.0
Ballast "A"	127°	105°	25	107	71.9
Ballast "B"	119°	104°	27	104	69.8

GLASS BOTTOM — 6-LAMP RECESSED TROFFER

ADVANCE CAT. NO. RSH-2E75-S	91°	76°	22	115	77.2
Ballast "A"	113°	91°	23	105	70.4
Ballast "B"	105°	94.5°	25	102	68.3

GLASS BOTTOM — 4-LAMP RECESSED TROFFER

ADVANCE CAT. NO. RSH-2E75-S	99°	86°	22	111	74.5
Ballast "A"	120°	101°	24	104	69.8
Ballast "B"	117°	102°	27	100	67.3

*TEST DATA COMPUTED WITH CERTIFIED (CBM) BALLASTS AND (2)F96T12 LAMPS.

The new ADVANCE KOOL KOIL Fluorescent Lamp Ballast is the greatest forward step in the history of fluorescent lighting . . . IT SOLVES THE HEAT PROBLEM!

This ADVANCEment required three years of exhaustive research, development and testing new grades of steel, wire, insulation and compounds. As a result, ADVANCE now brings the lighting industry the new KOOL KOIL series-sequence ballast that operates 15 to 20 degrees cooler, gives 15% more light output and increases ballast life 3½ to 4 times.

TECHNICAL DATA—ADVANCE KOOL KOIL BALLAST—CAT. No. RSH-2E75-S

CATALOG NUMBER	LAMP TYPE	NOMINAL LAMP WATTS	RATED LAMP CIRCUIT M.A.	CIRCUIT VOLTAGE	LINE CURRENT (AMPS)	WATTS LOSS	OPEN CIRCUIT VOLTAGE	DIMENSIONS IN INCHES			
								LENGTH	WIDTH	HEIGHT	MOUNTING
RSH-2E75-S	(2)F96T12	74	430	118	1.5	24	775	14 5/16"	3 7/64"	1 25/32"	13 3/4"
	(2)F72T12	55	430	118	1.5	24	775	14 5/16"	3 7/64"	1 25/32"	13 3/4"

(Continued from page 15A)

trical contacts is conducted by the University's Department of Electrical Engineering and General Extension, with the cooperation of the Stackpole Carbon Co. and other manufacturers and users of electrical contacts. Ralph E. Armington, associate professor of electrical engineering is the seminar chairman.

Two sessions, conducted on a lecture-discussion basis, will be held each day. Small group discussions on topics selected by those enrolled in the seminar are planned for the afternoons of the second and third days. Each discussion group will include at least one qualified expert.

Further information may be obtained from Professor Armington at 104 Electrical Engineering Building, The Pennsylvania State University, University Park, Pa.

Merchants Groups Co-Sponsor CLI-IES Store Lighting Clinic

Eight merchants' and industry organizations joined with the Chicago Lighting Institute and the Chicago Section of I.E.S. in sponsoring a clinic on Store Lighting, April 23. The program was planned for the merchants, store managers, display managers, architects and lighting engineers, and covered the following topics:

Morning Session

Introductory Remarks, Let There Be Light — Joseph T. Meek, President Illinois Retail Merchants Association, *Chairman*.
Fluorescent and Incandescent Light — Robert L. Allen, Westinghouse Electric Corp., Lamp Division.
Color and Light for Appeal and Sales Stimulator — L. E. Innis, Sylvania Electric Products Inc.
How to Light a Window to Attract Customers — William Zuehsow, Curtis Lighting Inc.

Afternoon Session

Fred Goerlitz, Chicago Retail Merchants Association, *Chairman*.
Tour of Institute Quarters — CLI Staff Members Kerr Sanders, Herman Sereika, Raymond Wozniak.
Good Maintenance Pays — Jerome Gimbel, Sun-Ray Fluorescent Co.
How to Create Effective Display Lighting — John Madden, W. L. Stensgaard and Associates, Inc.
Trends in Store Lighting — Walter Sobel, Sobel and Stein, Architects.
Panel and Audience Discussion.

The organizations co-sponsoring the clinic, with the I.E.S. Section and the Institute, were:

Chicago Retail Merchants Association,
Illinois Retail Merchants Association,
Associated Fur Industries of Chicago,
Associated Food Retailers of Chicago,
Associated Retail Bakers of Greater Chicago,
Chicago Restaurant Association.

(Continued on page 20A)

leaves from the... HISTORICAL COMMITTEE'S SCRAPBOOK

Lighting for Professional Football

This story was told by that beloved former Columbia University coach, Lou Little, a long time ago.

When, after a football career at Penn, he "turned pro" in the fall of 1920, the business of professional sports was novel, unpredictable, and not too remunerative. In order to accommodate the players, mostly men who could practice only at night, a typical football team such as the Frankford Yellow Jackets of Philadelphia had to practice under artificial light. But where?

Funds — and illuminants such as the mammoth floodlighting installations of today — were just not available. If there were any outdoor athletic field lighting jobs, they had more of the characteristics of a *trickle*, rather than a *flood*.

So, to conserve resources and still have a dependably illuminated practice field, the team played each night just outside the walls of the Holmesburg Prison (near the Pennsylvania Railroad in suburban Philadelphia), where the lights on the top of the prison wall flooded the patch of ground where the teams practiced. This lighting was always on. And it was free!

The teams were requested not to practice too late, for fear of disturbing the prisoners, or perhaps making them envious because the game was on the other side of the wall. But, for economy and dependability, that sports lighting system of thirty-eight years ago, however meager in its pioneering features, has not yet been exceeded in its practical ingenuity.

JUDGES and winners in the Alabama Section's contest for My Most Interesting Lighting Job are, left to right, photo at left: judges Joe Pettyjohn, Judd Lough, Evan Terry and H. D. Mosley; photo at right; winners, Sam Davidson, first in Class II; G. A. Bates, first in Class I; Ralph Bynum, third in Class II. C. E. Parrish, second in Class II was not present at time of photograph. The contest was held at the Section's March 24 dinner meeting.

(*Continued from page* 19A)

Chicago Retail Hardware and Paint Association,
Jewelers Association of Greater Chicago.

A demonstration of the "Light Center" at the Institute was conducted by Carl W. Zersen, Managing Director. Luncheon was served in the Institute's Gallery of Light.

Back Issues of I.E. Wanted

The Pergamon Institute, of London, reports an urgent need of a complete set of *I.E.S. Transactions* and ILLUMINATING ENGINEERING, from the first issue in 1906 to the end of 1957. If any reader has these back issues and wishes to dispose of them, he should send a list to the Institute which will submit an offer. The Institute, a non-profit foundation for the furtherance and dissemination of scientific knowledge, is located at 4-5 Fitzroy Square, London, W.1, England. R. Bigwood is Administrative Secretary.

To ALL IES MEMBERS:

This year's National Technical Conference has two tantalizing "extras." Its date — August 17 to 22 — and its site — across the border to Toronto, Canada. These add up to a rare opportunity for combining valuable conference sessions with a Canadian vacation.

The opportunities in that direction are, of course, endless. To name a few: The world-famed Canadian National Exhibition in Toronto opens August 21. This is the largest annual exhibition in the world, and in itself is worth a special journey. Niagara Falls is only a short trip from Toronto. Here, the Falls have recently been relighted, extending into the night hours, even enhancing the majesty of this spectacle.

Our Canadian friends are planning great things for the Conference itself. Forty papers are scheduled. Their titles suggest technical sessions of major importance; some a glimpse at future trends. Also on the preliminary program is an afternoon's session planned by the Residence Lighting Forum, and of course, the popular session on the year's Lighting Progress. The program shows Wednesday morning devoted to the contest for "My Most Interesting Lighting Job," but Wednesday afternoon has been left open. From my knowledge of the planning going on, there are some exciting possibilities in this circumstance!

Let's all meet at the Royal York in Toronto, August 17. It's the largest hotel in the British Commonwealth, and from the opening session on, will be bustling with important IES affairs, technical sessions and good fellowship!

Sincerely,
KIRK M. REID
President, I.E.S.

ABOUT PEOPLE

Frank X. Blackwell has been appointed vice-president of Supreme Lighting Co., Los Angeles. Mr. Blackwell, who will also continue as sales manager for the company, will be assisted in that capacity by **E. William Ross. Sy Hughes** will be in charge of architectural and engineering contacts and will also supervise the firm's new products research.

The management of Pittsburgh Reflector Co. has announced the appointment of **Charles S. Kernaghan** to the position of general sales manager. Mr. Kernaghan was formerly vice-president in charge of merchandising for Hubbard and Co., Pittsburgh, and prior to that was associated with the Waterman Pen Co. Pittsburgh Reflector has also announced the signing of two sales representatives. **Paul Angrick,** most recently a lighting engineer with Engineering Products will cover the Indianapolis sales territory and **James F. Ligon,** a former consultant-lecturer for the Chicago Lighting Institute, will handle sales in the Cincinnati area, including Ohio, West Virginia and Kentucky.

Ownership of Sola Electric Co., Chicago has been acquired by Basic Products Corp. of Milwaukee. Under an agreement ratified at a March 29 meeting of Basic stockholders, Sola Electric will continue to operate under its present management, **Joseph G. Sola,** president, as a division of Basic Products.

Allan Schwartz has been named industrial sales manager of The Frankelite Co., Cleveland. In his new position as head of the industrial department, Mr. Schwartz will service greater Cleveland's industrial plants and electrical contractors.

J. R. MacDonald, chairman of the board and president of General Cable Corp., has been elected treasurer of NEMA for the ensuing year. Mr. MacDonald, a member of the Association's board of governors for the past six years, succeeds **B. C. Neece,** president of Landers, Frary and Clark, who resigned from the NEMA board because of business pressures within his own company.

John C. Virden Co., Cleveland, has announced the appointment of two more sales representatives: **Thomas L. Leslie, Jr.,** for the New England states (except Connecticut) and eastern New York, and **William M. Lovell** for the Kansas and Missouri area. Mr. Leslie, who will make his headquarters in Boston, comes to Virden from the Hartford Rayon Corp. where he was district sales manager. Mr. Lovell was formerly with the Emerson Pryne Co. in Michigan.

N. J. MacDonald, president of Thomas & Betts Co., Elizabeth, N. J., was elected chairman of the National Electrical Week Committee, succeeding **Merrill E. Skinner** of Union Electric Co., St. Louis, who has led the program for the past three years.

Three new sales representatives have been appointed by the Frink Corp. of New York. **Barney H. Hartley,** of Phoenix, Charter Chairman of the Arizona Section of I.E.S. will cover the Arizona territory, **George Montgomery,** Waban, Mass. will be the representative in New England and **C. J. Sampson** and Son, St. Louis will be responsible for sales in Missouri. Mr. Sampson was with General Electric for 20 years, holding the position of district sales manager for the General Electric Supply Co. in St. Louis for many years.

James F. Best of Indianapolis has been signed as sales representative for the Moe Light Division of Thomas Industries, Louisville, Ky. Mr. Best was sales manager of the Dairy Division of the Indiana Farm Bureau Co-op prior to this appointment.

L. N. Grawemeyer, who for the past

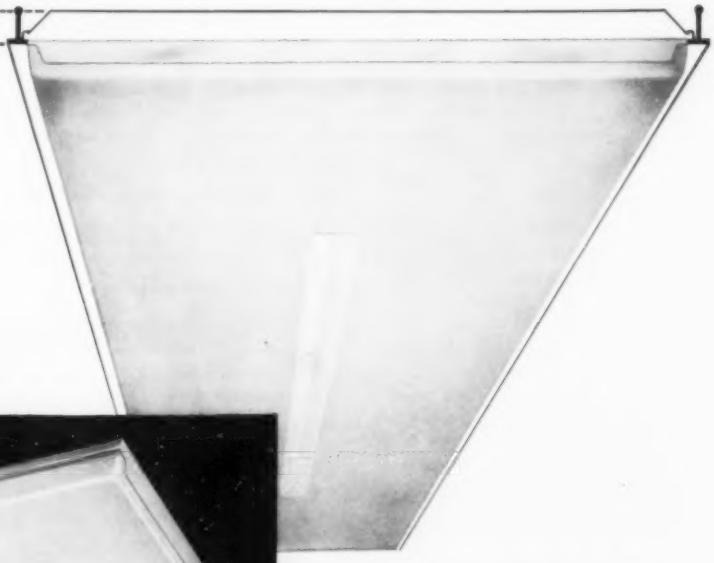
(*Continued on page* 22A)

Now . . . a troffer so shallow it handles like tile!

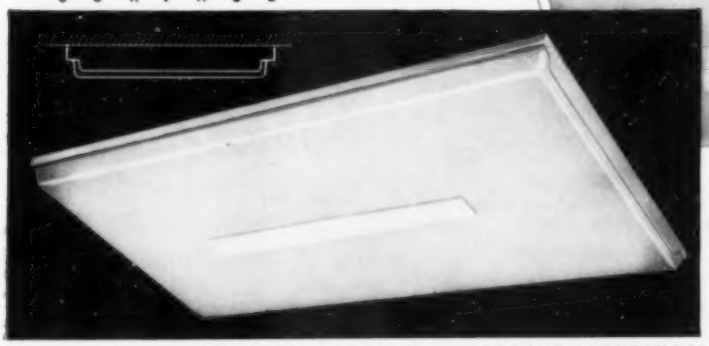
SMITHCRAFT SLENDEX

Introducing the slender, sleek Smithcraft SLENDEX. A unique, practical answer to the absolute *minimum cavity—low ceiling* conditions dictated so often by today's construction economies. Recesses only 1⅜" . . . less than the depth of most ceiling supporting members . . . eliminates cost of cutting these members. One-man installation. Goes in FLAT, requires no extra depth for tilting. Adapts to most of today's common ceilings. 1′ x 4′ units for 2 Rapid-Start Lamps or 2′ x 4′ units for 4 Rapid-Start Lamps. Here is a clean, smoothly-styled lighting answer to a common contemporary building problem . . . simple, efficient and pleasing!

RECESSED 1 ⅜ "



SURFACE



SLENDEX *Surface Units are shallow, too. Slim, trim and clean, with no light leaks, and with no dark center streak. Fixture depth 1⅜" — overall depth, including shielding, only 3".*

Smithcraft — "AMERICA'S FINEST FLUORESCENT LIGHTING"

Smithcraft LIGHTING
CHELSEA 50, MASS.

THE MAN FROM SMITHCRAFT
Paul Wehner, Dayton, Ohio representative. Like every member of Smithcraft's nationwide organization he can help you turn any lighting purchase into a profitable lighting investment. Ask the man from Smithcraft about the new SLENDEX.

PLEASE ATTACH TO YOUR BUSINESS LETTERHEAD and mail to

Smithcraft LIGHTING, CHELSEA 50, MASS.

NAME_____

TITLE_____ CO._____

ADDRESS_____ CITY_____ STATE_____

☐ Please send me the monthly publication, "Light Side of the News", so that I can keep in touch with the latest trends in lighting.

☐ Please send me catalog information on the NEW Smithcraft SLENDEX.

☐ Please send me the complete SMITHCRAFT CATALOG, containing data on America's Finest Fluorescent Equipment.

CERTIFICATES of Emeritus status are presented to (photo at left) Earl Anderson, Fellow Emeritus; and (photo at right) to Frank G. Horton, Member Emeritus.

James F. Finn (at right in both photos), Chairman of the Michigan Section made the presentations. Over 125 members and guests were present at the March 11 meeting.

(*Continued from page* 20A)

six years has been vice-president in charge of sales at the Miller Co., Meriden, Conn., announced his resignation recently. Mr. Grawemeyer said that he plans to enter new activities which he will disclose at a later date. As vice-president, he was responsible for the firm's four sales regions as well as for advertising, sales promotion, application engineering, inside sales and export sales. The rest of his 30 years with the Miller Co. were spent in field sales in Atlanta and Philadelphia.

The appointment of **James F. Canning** as sales promotion manager for Sylvania Lighting Products, a division of Sylvania Electric Products, Inc., has been announced. Mr. Canning has been a member of the Division's advertising and sales promotion department since 1955 when he joined Sylvania. Prior to this association, he served as New England district manager for Westinghouse Electric Corp.

Sunbeam Lighting Co., Los Angeles, has announced the appointment of **L. S. Reed** & Co., Denver as sales representative for the Colorado-Wyoming area, and **Perry G. Sessoms, Jr.** of Atlanta as agent for the Georgia-Alabama area. Mr. Reed is currently vice-president of the Rocky Mountain Section of I.E.S.

Deaths

H. M. Clunk, Eastern Pennsylvania Section.
Selene Hunt, Southeast Florida Section.
Lucian Charles Priest, New England Section.
Thomas C. Stone, Cornhusker Section.

NEW MEMBERS

On recommendation of the Board of Examiners, the following were elected to membership on April 10. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

Associate Member:
Wilson, F. B., City of Huntsville Electric System, Huntsville, Ala.

ALAMO SECTION

Associate Member:
Miller, E. H., Jr., Westinghouse Electric Supply Co., San Antonio, Texas.

ARK-LA-TEX CHAPTER

Associate Member:
Martin, E. R., Neild-Somdall-Smitherman & Associates, Shreveport, La.

BLUE NOSE CHAPTER

Associate Member:
Matheson, D. T., Bryant Electric Co. Ltd., Halifax, N. S.

CAPITAL SECTION

Member:
Wilson, S. W., National Bureau of Standards, Washington, D. C.

Associate Members:
David, A. R., Bureau of Ships, Department of Navy, Washington, D. C.
Morrow, Frances M., Mayer & Co., Washington, D. C.

CENTRAL NEW YORK SECTION

Member:
*Swanson, R. C., Jr., Niagara Mohawk Power Corp., Syracuse, N. Y.

Associate Members:
Bradley, R. C., Cornell University, Ithaca, N. Y.
Laver, F. W., F. Walker Laver & Son, Utica, N. Y.
Shannon, R. B., Kay-R Electric Corp., Syracuse, N. Y.

CENTRAL OKLAHOMA CHAPTER

Associate Members:
Cavanaugh, J. V., Graybar Electric Co., Oklahoma City, Okla.
Gallien, Henry III, General Electric Co., Oklahome City, Okla.
Herrmann, D. C., Westinghouse Electric Supply Co., Oklahoma City, Okla.
Hughes, A. C., Graybar Electric Co., Oklahoma City, Okla.
Krueger, J. E., Otto Krueger Electric Co., Oklahoma City, Okla.
Landon, G. K., Board of Education, Oklahoma City, Okla.
Nott, A. E., The A. E. Nott Electric Co. Inc., Oklahoma City, Okla.
Ransbarger, F. D., Electric Supply of Oklahoma, Oklahoma City, Okla.
Snyder, C. D., Weatherbee Electric Co., Oklahoma City, Okla.
Walker, D. E., Gaddis Walker Electric Co., Oklahoma City, Okla.
Weir, D. L., Boyington Electric Co., Oklahoma City, Okla.

CHICAGO SECTION

Members:
Hartman, E. A., Pioneer Service & Engineering Co., Chicago, Ill.
Meyer, K. W., Wilson Electric Co., Rockford, Ill.

Associate Member:
Schuster, Henry, Efengee Electric Supply Co., Chicago, Ill.

CHINOOK CHAPTER

Associate Member:
Smith, R. M., Northern Electric Co. Ltd., Calgary, Alta.

CLEVELAND SECTION

Members:
Anderson, M. R., Westinghouse Electric Corp., Cleveland, Ohio.
Husby, D. E., Westinghouse Electric Corp., Cleveland, Ohio.
Waldbauer, W. M., Westinghouse Electric Corp., Cleveland, Ohio.

COASTAL BEND CHAPTER

Member:
Scott, R. G., Westinghouse Electric Supply Co., Corpus Christi, Texas.

(*Continued on page* 25A)

NEW! and packed with profits!

the virden Sunshine® Ceiling

V-8046. Complete packaged ceiling $73.25 list. Slightly higher west of the Rockies.

A 4′ x 6′ "Packaged" Unit for Bathrooms, Kitchens For New Homes...Old Homes...Modernization

The new Virden Sunshine Ceiling.* A complete packaged unit that installs quickly and easily to any ceiling surface. Electrical channel system fastens to ceiling — satin white suspended grid holds plastic diffusers (8½″ drop). Uses six 100W incandescent lamps to flood the room with even, glare-free "sunshine". A sure-fire sales clincher in new homes. A terrific plus-profit maker for use in existing homes or on modernization jobs.

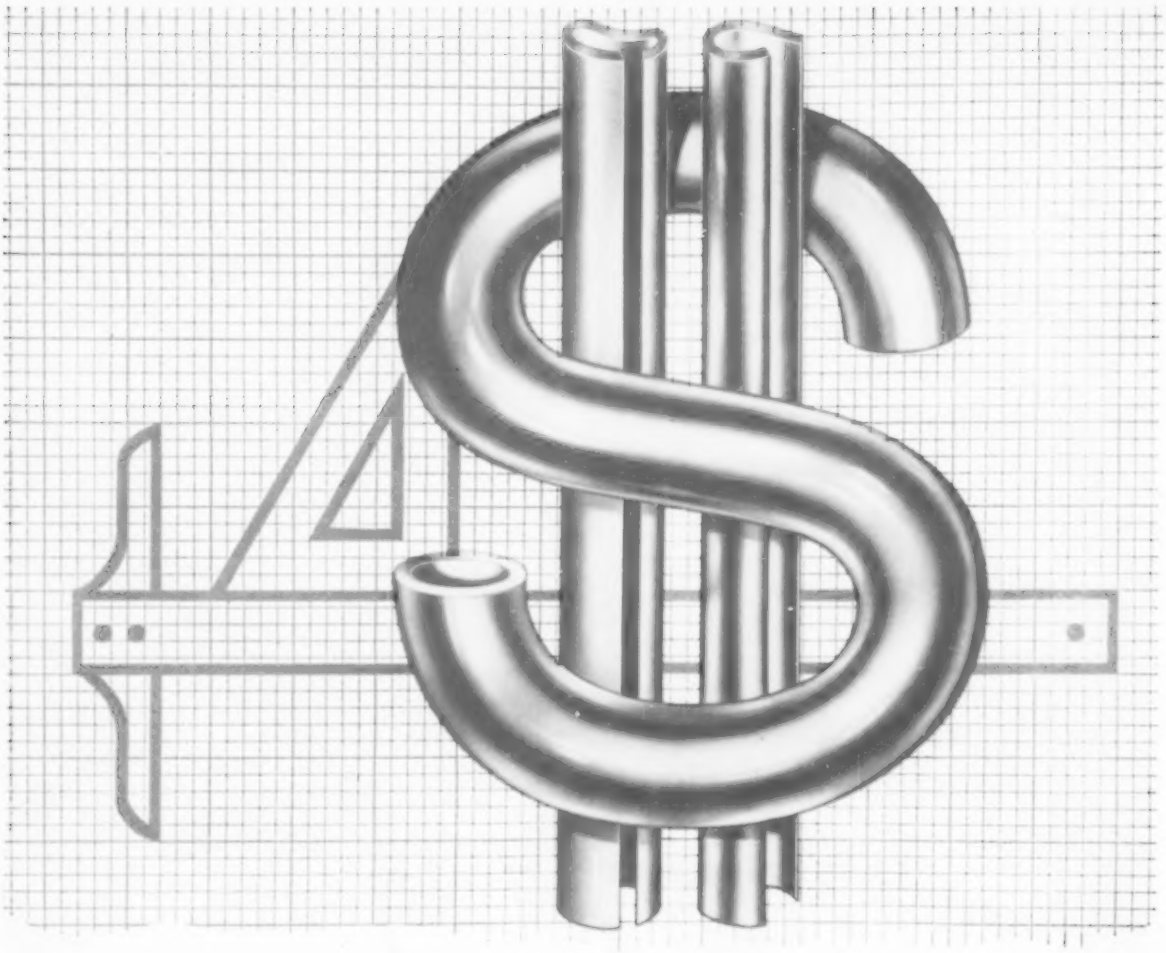
Luminous ceilings promise to be the next big development in home lighting. Virden brings it to you now in a complete easy-to-install package. Plan now to use it in your next job, new or old. See the model now on display at your Virden distributor, or write John C. Virden Co., Dept. IE, 6103 Longfellow Ave., Cleveland 3, Ohio.

VIRDEN Lighting®

virden

Member American Home Lighting Institute

* Patent No. 2,659,807



KSH PLASTIC ENGINEERING

. . . helps put your product in profitable shape

WE EXTRUDE PROBLEMS INTO PROFIT-MAKERS

KSH engineers will work hand-in-hand with your designers . . . to demonstrate how high quality plastic extrusions can add extra sales appeal to your product.

You will learn that KSH extruded plastics improve the function and appearance of products . . . while substantially reducing production costs!

DESIGNERS • ENGINEERS • MANUFACTURERS

KSH

SALES OFFICES

KSH PLASTICS, INC., HIGH RIDGE, MO.

CHICAGO, ILL. • MILWAUKEE, WIS. • INDIANAPOLIS, IND.
DAYTON, OHIO • ATLANTA, GA. • GRAND RAPIDS, MICH.
ST. LOUIS, MO. • RED BANK, N. J. • BOSTON, MASS.

(*Continued from page 22A*)

COASTAL EMPIRE CHAPTER

Associate Member:

Harrod, W. T., Jr., Westinghouse Electric Supply Co., Savannah, Ga.

CONNECTICUT SECTION

Associate Member:

Lorenz, H. F., The L. C. Doane Co., Essex, Conn.

CORNHUSKER SECTION

Associate Members:

Brewer, R. W., Iowa Public Service Co., Sioux City, Iowa.
Hagen, C. L., 18 1st St. N. E., LeMars, Iowa.
Kirkpatrick, F. D., Westinghouse Electric Corp., Sioux City, Iowa.

EASTERN PENNSYLVANIA SECTION

Members:

Gernerd, H. W., Gilbert Associates Inc., Reading, Pa.
Kline, R. M., Metropolitan Edison Co., Reading, Pa.
Robinson, W. R., Dauphin Electrical Supplies Co., Harrisburg, Pa.
*Schaeffer, J. B., General Electric Supply Co., Reading, Pa.
*Solley, G. E., Pennsylvania Power & Light Co., Allentown, Pa.

Associate Members:

Anthony, Frank, Pennsylvania Power & Light Co., Allentown, Pa.
Balsbaugh, W. S., Jr., Lacy, Atherton & Davis, Harrisburg, Pa.
Bottorf, J. W., William A. Robinson Associates, Inc., Harrisburg, Pa.
Hawk, F. E., Pennsylvania Power & Light Co., Allentown, Pa.
Mace, Dale O., Mace Co., Harrisburg, Pa.
Merron, A. E. B., Lightolier Co., Harrisburg, Pa.
Price, A. F., Pennsylvania Power & Light Co., Allentown, Pa.

EDMONTON CHAPTER

Associate Members:

Barker, T. R., Carl Tomlinson Electric Ltd., Edmonton, Alta.
Lowry, H. B., Cochrane Stephenson (Western) Ltd., Edmonton, Alta.
Meldrum, R. G., Canadian Westinghouse Co. Ltd., Edmonton, Alta.

FOREIGN NON-SECTION

Members:

Habro, Bertil, AB Ingeniorfirman Alex Philip, Stockholm, Sweden.
Krumins, G., AB Ingeniorfirman Axel Philip, Stockholm, Sweden.
Sweeney, R. E., General Electric de Venauela S.A., Caracas, Venezuela.

Associate Members:

Fellmer, Reinhold, Bumix-Mischlicht, G.M.B.H., Wurttemberg, Germany.
Page, A. E., The General Electric Co. Ltd., London, England.
Willoughby, A. H., The General Electric Co., Ltd., London, England.

GEORGIA SECTION

Associate Member:

Heath, C. E., General Electric Co., Atlanta, Ga.

GOLDEN GATE SECTION

Associate Members:

Ackerman, J. M., Ackerman & Aronoff, Palo Alto, Calif.
Haskel, Poe, Sunray Products Corp., San Francisco, Calif.
Hirschfeld, R. L., Crescent Electric Supply Corp., San Francisco, Calif.

HEART OF AMERICA SECTION

Associate Member:

Clark, T. K., Moore & Clark, Engineers, Topeka, Kans.

INDIANA SECTION

Member:

Mead, H. C., General Motors Corp., Anderson, Ind.

Associate Members:

Adams, Cecil, The Scott Jaqua Co. Inc., Indianapolis, Ind.
Cockrum, R. E., Civil Aeronautics Admin., Technical Development, Indianapolis, Ind.

IOWA SECTION

Member:

*Stafford, Mrs. Mary E., Thomas Electric Co., Des Moines, Iowa.

Associate Member:

Stroh, C. R., Stroh Plumbing & Electric Co., Des Moines, Iowa.

MARITIME CHAPTER

Associate Member:

McFarlane, R. W., Electric Service League, St. John, N. B.

MARYLAND SECTION

Associate Member:

Cunningham, G. T., Whitman, Requardt & Associates, Baltimore, Md.

MICHIGAN SECTION

Members:

Bjornson, N. R., Giffels & Rossetti, Detroit, Mich.
Ling, Der-Shyang, Eberle M. Smith Associates, Inc., Detroit, Mich.
Schagane, C. W., Advance Electric Supply Co., Flint, Mich.

Associate Members:

Adams, W. A., Giffels & Rossetti, Detroit, Mich.
Bailey, T. B., General Electric Co., Detroit, Mich.

Regional Conferences Only Two More To Go

As this issue of I. E. rolls off the press, there are only two remaining Regional Conferences this year. These are:

Pacific Northwest, May 22-24, Multnomah Hotel, Portland, Oregon.

Great Lakes, June 23-24, Sheraton Hotel, Rochester, New York.

MID-SOUTH CHAPTER

Associate Member:

Hooper, C. D., Memphis Light, Gas & Water Div., Memphis, Tenn.

MILWAUKEE SECTION

Associate Members:

Ames, C. R., Harold R. Ames, Architect, Madison, Wis.
Blise, R. A., Wisconsin Electric Power Co., Kenosha, Wis.
Holz, R. L., Wisconsin Electric Power Co., Kenosha, Wis.
Scharch, G. J., Square D Co., Milwaukee, Wis.
Yakich, V. J., Line Material Industries, South Milwaukee, Wis.

MONTREAL SECTION

Members:

*Cohen, I. E., Rest-Glow Mfg. Co. Ltd., Montreal, Que.
Malkin, Alfred, MacArthur, Malkin & Co., Montreal, Que.
Meland, Sam, Standard Electric Co. Inc., Mt. Royal, Que.
*Montcalm, Yvan, Powerlite Devices Ltd., Montreal, Que.

MOTHER LODE CHAPTER

Associate Members:

Langston, Kyle, Hill Bros. Electrical Contractors, North Sacramento, Calif.
Van Nostrand, L. J., Day-Brite Lighting Inc. of California, Santa Clara, Calif.

NEW ENGLAND SECTION

Associate Members:

Butler, H. H., A. L. Smith Iron Co., Lighting Division, Chelsea, Mass.
Black, W. H., Power Electrical Co. Inc., Wakefield, Mass.
Chopoorian, Meshach, Jackson & Moreland Inc., Boston, Mass.
Krippendorf, W. P., Wheeler Reflector Co., Boston, Mass.
Rickerd, W. C., Edwin F. Guth Co. of St. Louis, 23 Woodside Ave., Braintree, Mass.

NEW MEXICO CHAPTER

Members:

McIntyre, M. V., 530 Jefferson N. E., Albuquerque, N. M.
*Pearce, J. E., Day-Brite Lighting Inc., Albuquerque, N. M.

Associate Members:

Cainski, R. C., Public Service Co. of N. M., Albuquerque, N. M.
Gamertsfelder, P. R., Public Service Co. of New Mexico, Belen, N. M.

NEW ORLEANS SECTION

Members:

*Kleinschmidt, C. C., Associated Manufacturers Agents, New Orleans, La.
*Schroeder, G. C., Jr., Schroeder & Associates, New Orleans, La.

(*Continued on page 46A*)

I.E.S. National Technical Conferences

1958 — August 17-22 — Royal York Hotel, Toronto, Ontario

1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California

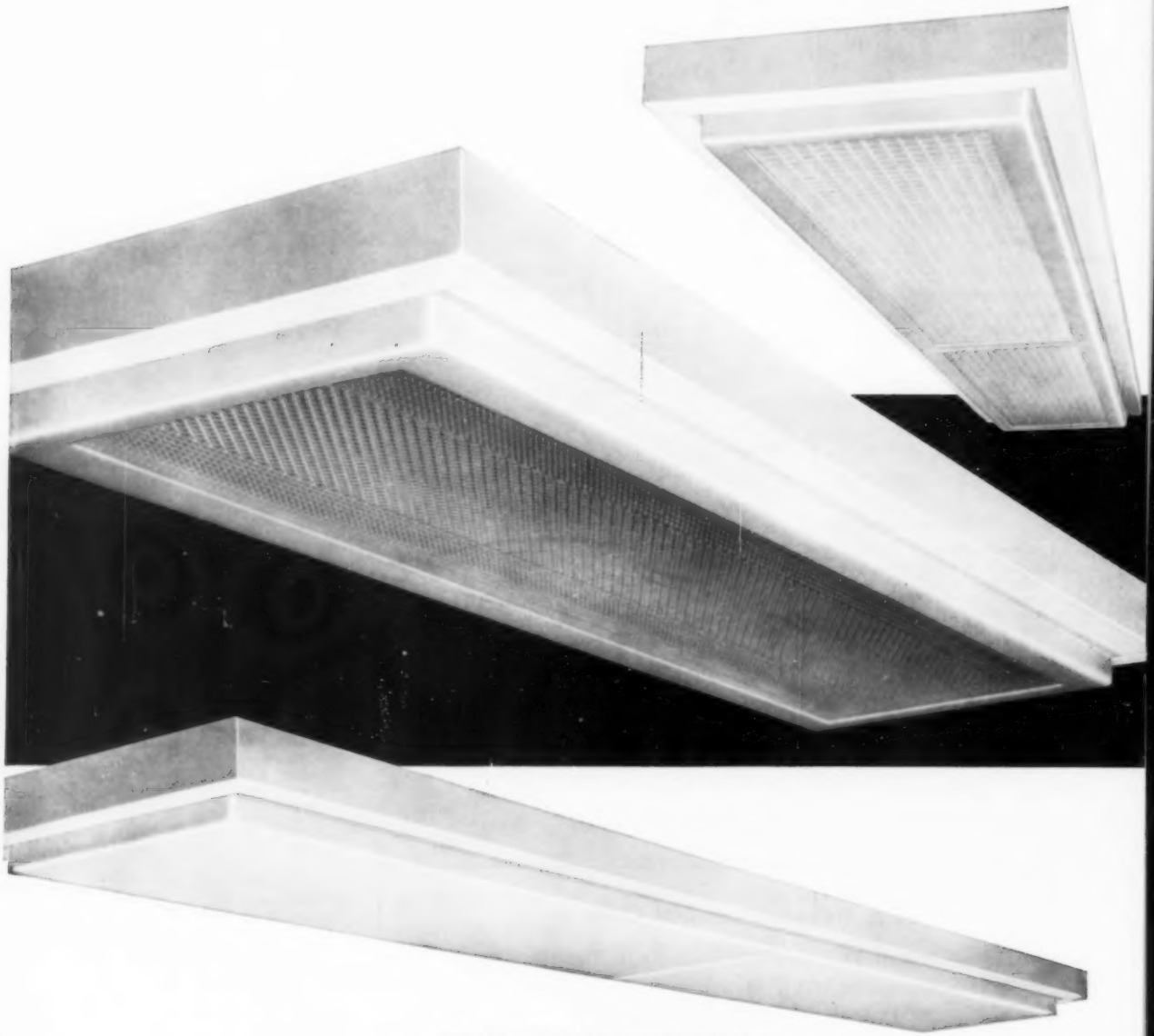
1960 — September 11-16 — Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961 — September 24-29 — Chase Park Plaza Hotel, St. Louis, Missouri

1962 — September 9-14 — Statler-Hilton Hotel, Dallas, Texas

NEW from Westinghouse

SURFLINERS



SELECTION OF SHIELDINGS

SURFLINERS offer the preferred plain, dished-plastic shields—45° clear, open louvers in plastic—popular Opti-Kube lenses—or the high-quality Holophane 6018 lens. Housing plus deepest shield still totals less than 3⅝ inches. Decorative end-covers come complete with self-tapping screws.

Thinner! Wider! Planned by Architects!

DESIGN-ENGINEERED TO DELIVER FULL BALLAST LIFE!

Here is a new, advanced luminaire—planned by architects—to enhance the design of ceilings for office or store lighting. Yet it is a luminaire that also *avoids the problem of overheating ballasts!*

It is the SURFLINER—engineered by Westinghouse! Of crisp, clean, simple lines! Providing *various* levels of light! With excellent efficiency and high quality of illumination. For fast surface-mounting. Still with a striking, "fresh," modern appearance!

Unique translucent doors of "basket" design accommodate a selection of the most preferred shieldings—and provide all-luminous "shafts" across ceilings, to emphasize esthetic plans.

New dimensions of 16½ inches in width—by lengths of 4 or 8 feet—and an extremely shallow, only 2½-inch housing—create a part-of-the-ceiling appearance, provide proportions ideal for modern design!

What's more, these new SURFLINERS take ballasts away from the critical heat-chamber area—actually prolong ballast life and lamp efficiency!

The ballasts in SURFLINERS are *not* located between the lamps!—where serious overheating can drastically cut ballast life! Instead, they are off to one side and shielded by the reflector! SURFLINER CBM ballasts *stay* cooler—*maintain* operation within proper prescribed standards!

SURFLINER housings are light in weight, with reinforcing ribs. Sturdy ⅛-inch styrene "basket" doors eliminate need for door frames—have no metal parts—supply their own latch-and-hinge arrangement.

FLEXIBLE Lighting Efficiency—2, 3 or 4 Lamps! Universal Application!

It's easy to detail efficient lighting layouts with SURFLINERS! Choice of 2-3-or 4 lamps—within various fixtures—as they may be indicated in the same luminaire rows—now provides proper lighting levels, as various areas within the same room may require!

Moreover, the sides of SURFLINER "basket" doors—on extremely shallow housings—even provide some upward component of light. Give excellent diffusion throughout the lighted area, with low contrasts and complete light distribution!

The mounting of SURFLINERS, either singly or in continuous rows, is simple. Pre-assembly and prewiring for either-end hook-up save installation time!

This combination of SURFLINER features and qualities makes SURFLINERS preferred by architects for lighting stores — offices — schools — banks — public buildings, everywhere.

Get the complete information on low-cost SURFLINERS! Call your nearest Westinghouse Representative today! Or, write for Lighting Specialist assistance immediately to: Westinghouse Electric Corporation, LIGHTING DIVISION, Edgewater Park, Cleveland, O.

YOU CAN BE SURE...IF IT'S

Westinghouse

J-04439

Certified Lighting

NO BLUE SMOKE HERE

When the Channing Corporation required new offices at 85 Broad Street, New York, they handed designers L. G. Sherburne Associates a tough problem; bringing a structure built in 1920 completely up to date. These pictures are ample evidence that the designers more than licked the problem. Here Channing's main Conference Room is bathed in an abundance of glare-free light from recessed ceiling fixtures, shielded to very low surface brightness with Honeylite by Hexcel Products Inc. A single switch closes the curtain across the glass wall, boosts illumination and starts an exhaust blower which draws air at low velocity through panels of Honeylite, finest lighting ever, without a shadow of a doubt.

38 years younger | thanks to Honeylite

NO "FIXED" LIGHTING HERE

In Channing's Sales Management offices flush ceiling lighting is shielded with panels of Honeylite aluminum honeycomb in 2 x 4 foot modules, dropped in the ceiling grid of exposed tee rails on 2 foot centers. Just as the office partitions can be demounted and relocated, lighting units can also be easily shifted. Lighting is both flexible and free from surface glare.

NO HARSH GLARE HERE

Lighting was the result of extensive research to achieve a high quality of illumination, not merely high intensity light. It was particularly desired to avoid the harsh, unhealthy glare so easily produced with high-output lamps in "efficient" fixtures. The designers selected the extremely low angular brightness of Honeylite aluminum honeycomb panels with their highly desirable downward transmission.

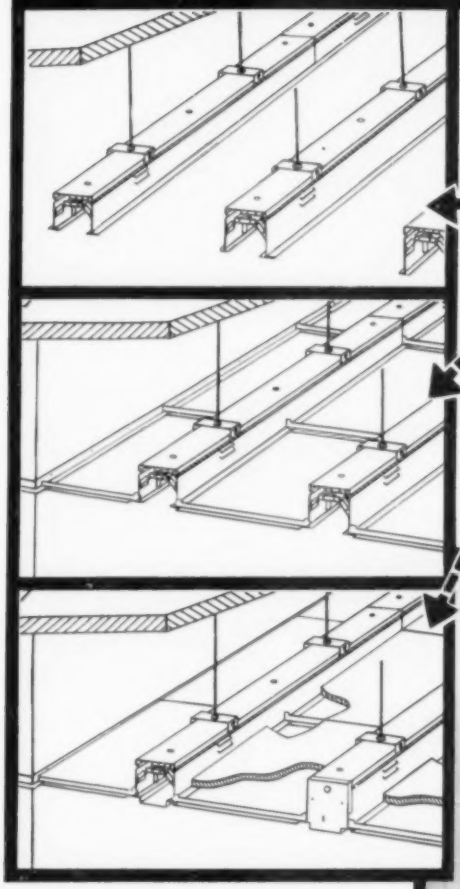
HONEYLITE®

LIGHT-DIFFUSING ALUMINUM HONEYCOMB
PRODUCED BY
HEXCEL PRODUCTS INC.
2741 9TH STREET, BERKELEY, CALIFORNIA

Another great engineering first from metco Lighting

Quiet-Light®

The lighting supports the ceiling!



NEW KIND OF LIGHTING AND ACOUSTICAL CEILING SYSTEM CUTS CONSTRUCTION COSTS

1. Install METCO QUIET-LIGHT recessed troffers. Space troffers for any desired illuminating level.
2. Install wall angles. Insert QUIET-LIGHT spacer bars between troffers and wall angles and rows of troffers.
3. Lay in acoustical panels on flanges of troffers, spacer bars and wall angles. Insert extruded polystyrene plastic diffusers in troffers.

RESULT:

Evenly diffused wall-to-wall quality lighting with efficient acoustics at lower cost . . . for offices, schools, libraries, drafting rooms, corridors, homes. Write for catalog and specification sheet today! **SOLD ONLY THROUGH QUALIFIED ELECTRICAL DISTRIBUTORS**

METALCRAFT PRODUCTS COMPANY, INC., MASCHER & LIPPINCOTT STS PHILADELPHIA 33, PA.

Get the most out of
Power-Groove with Day-Brite

CFI-15 fixtures for two 8-foot Power-Groove lamps furnish 60 foot-candles in high-bay areas of the All-Steel Equipment Co., Aurora, Ill. Under balconies, CFI-10 fixtures for High-Output Rapid-Start Lamps are used. HATFIELD ELECTRIC CO., *Electrical Contractor.*

Take advantage of the greater light output provided by Power-Groove lamps—*plus* the traditional installation and maintenance economies built into every Day-Brite fixture.

You get *both* when you install Day-Brite CFI (Comfort For Industry) industrial fixtures designed specifically for Power-Groove lamps.

Whether you have a high-, medium- or low-bay lighting problem, there's a Day-Brite CFI fixture to fit your requirements. For information, call your Day-Brite representative listed in the Yellow Pages, or write for Power-Groove booklet. Z-151

"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

Day-Brite Lighting, Inc., 6258 N. Broadway, St. Louis 15, Mo.
Day-Brite Lighting, Inc., of Calif., 530 Martin Ave., Santa Clara, Calif.

NATION'S LARGEST MANUFACTURER OF COMMERCIAL AND INDUSTRIAL LIGHTING EQUIPMENT

Regardless of luminaire design . . .

SPECIFY MONOTUBE POLES

for permanence • appearance • economy

• The nationwide acceptance and approval of Monotube street lighting poles is proved by the hundreds of thousands in use from coast to coast and abroad. Make sure your files contain the latest information on the range of pole and bracket designs available in aluminum and steel for every conceivable requirement.

Write to The Union Metal Manufacturing Company, Canton 5, Ohio.
In Canada: The Union Metal Manufacturing Company of Canada, Limited, Brampton, Ontario.

LIVE BETTER ELECTRICALLY

UNION METAL

Monotube Lighting Poles

When it comes to "SPECIALS" come to Jefferson

Jefferson not only offers the most complete line of standard catalog outdoor mercury lamp ballasts . . . Jefferson is the industry's PRIMARY SOURCE for CUSTOM-DESIGNED BALLASTS.

If you have a specific requirement—Jefferson can fulfill it . . . for example:

- A municipality needed an integral pole-mounted ballast for conversion of incandescent (100 and 175 watt ballasts mounted on 4" pole).
  JEFFERSON SUPPLIED IT!
- A large city needed a 400 watt ballast with an internal junction box with terminal block for original installation.
  JEFFERSON SUPPLIED IT!
- A Toll Road Commission needed a 2-lamp 400 watt ballast with 2 leads to each lamp.
  JEFFERSON SUPPLIED IT!
- A utility wanted a ballast with a special grounding lug.
  JEFFERSON SUPPLIED IT!
- A Park Commission needed direct burial ballasts in rubber cases for use on bridges and parkways.
  JEFFERSON SUPPLIED IT!
- A shopping center needed special adaptors for mounting in clusters on high towers.
  JEFFERSON SUPPLIED IT!
- A Seaway Project needed ballasts mounted in steel wire baskets.
  JEFFERSON SUPPLIED IT!
- An expressway needed ballasts that could be mounted directly in concrete retaining wall for underpasses.
  JEFFERSON SUPPLIED IT!

If a special ballast is needed . . . JEFFERSON SUPPLIES IT

Jefferson ELECTRIC COMPANY
Bellwood, Illinois

THE NEW miller RICHMOND

featuring...

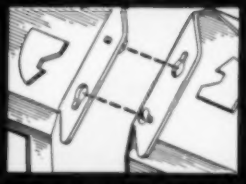
Luminous Texture-Lite Side Panels

Flexibility of Design and Application

for SCHOOLS • OFFICES • STORES

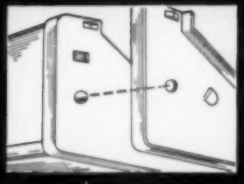
Unique, new decorative effects are possible with Texture-Lite side panels, a Miller exclusive, optional with Richmond. Open top lancings in the metal sides provide surface interest while shielding the lamps from direct view. Texture is accentuated and "brought to life" as light filters through the hooded openings. Appearance is softly luminous, subtle, and ever-changing. And with Texture-Lite the Richmond's clean, shallow styling is greatly enhanced.

Only The Richmond Offers These Features!

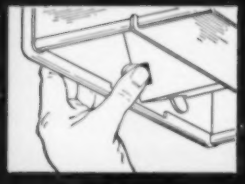


BUILT-IN CHANNEL CONNECTOR FOR 2 LP. UNITS . . . Facilitates continuous row installation. Connector is part of socket strap. No loose parts.

"U" SHAPED, TRANSLUCENT PLASTIC SIDE RAILS . . . Seat side panels; secure cross louver ends. Keep shielding assembly rigid and rattle-free. No dark strips.



AUTOMATIC ALIGNER CLIPS . . . Simplify alignment of shielding assemblies. Bump on clip lines up with hole in adjoining end plate—no adjustments.



"TWIN" THUMB LATCHES . . . at each end provide easy accessibility from either side of fixture. Shielding assembly is securely held but easily detached.

Miller's new Richmond Series offers an exciting and unique combination of features to meet both aesthetic and functional lighting design needs for schools, offices, and stores. Shallow, straight-sided, and cleanly styled — these fixtures provide wide flexibility of design and application. Richmonds are well engineered, sturdily built, and *attractively priced.*

Truly coordinated design throughout any installation is made possible by a choice of: Decorative Texture-Lite, Opaque Metal, or Plastic Side Panels; two different shielding assemblies; and 2 or 4-Lamp units in 4 or 8-ft. lengths.

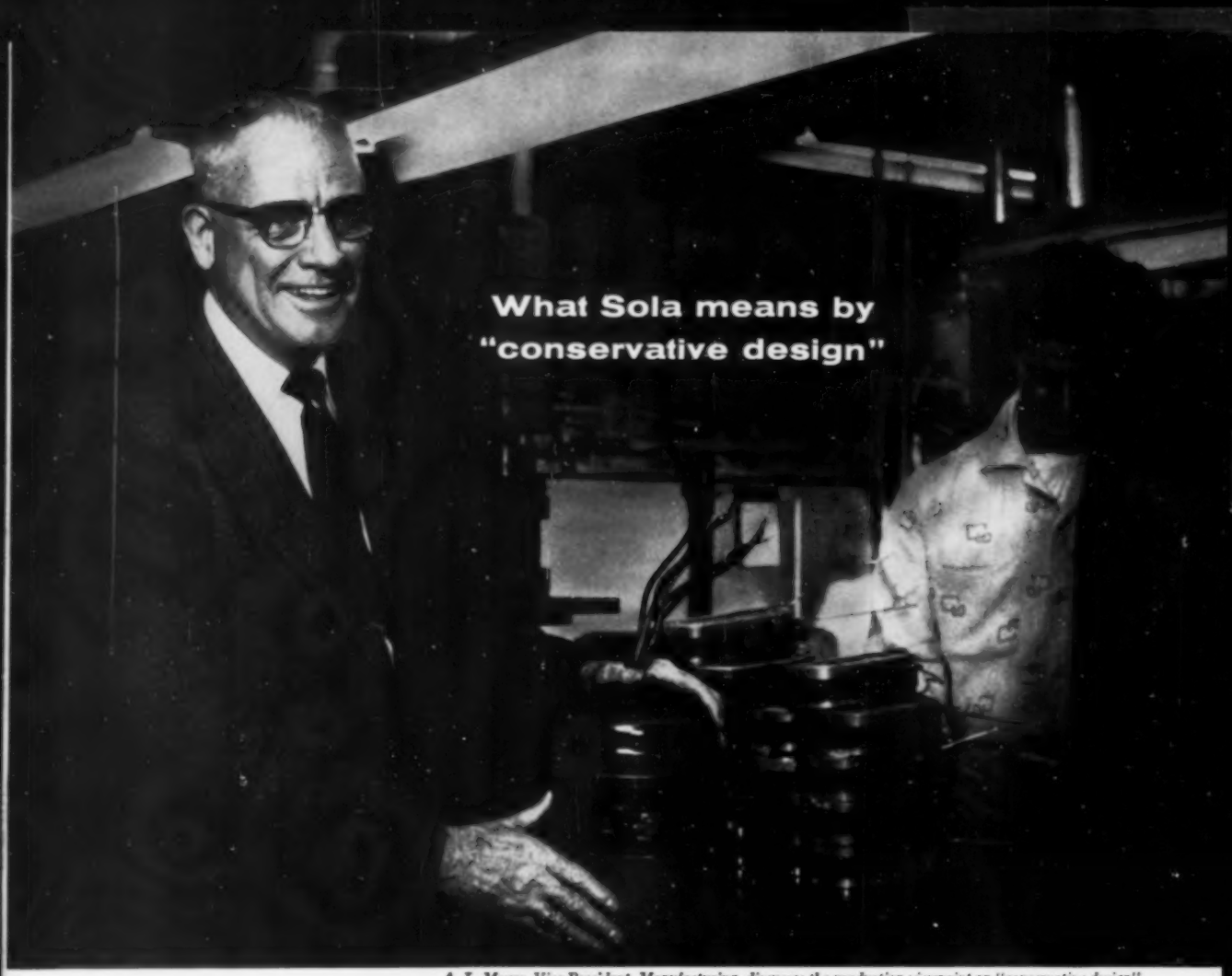
A subtle sparkle for added decorative effect is achieved on two of the Richmond units by means of a prismatic plastic strip. This strip provides 45° cross-wise shielding without increasing fixture depth.

For complete catalog information and performance data on the new Richmond contact your Miller Representative or write Dept. R-558, The Miller Company, Meriden, Conn.

THE miller COMPANY, MERIDEN, CONN.

In Canada: CURTIS LIGHTING OF CANADA LTD., TORONTO

miller
SINCE 1944



A. L. Myers, Vice President, Manufacturing, discusses the production viewpoint on "conservative design"

"We've found that building mercury lamp transformers 'over spec' actually boosts production"

When one of our constant-wattage mercury lamp transformers leaves the Sola plant, we know for certain that it will do the job for which it was intended. The reason we're so sure of this is that we build every transformer to exceed even Sola's own rigid engineering specifications by an ample margin.

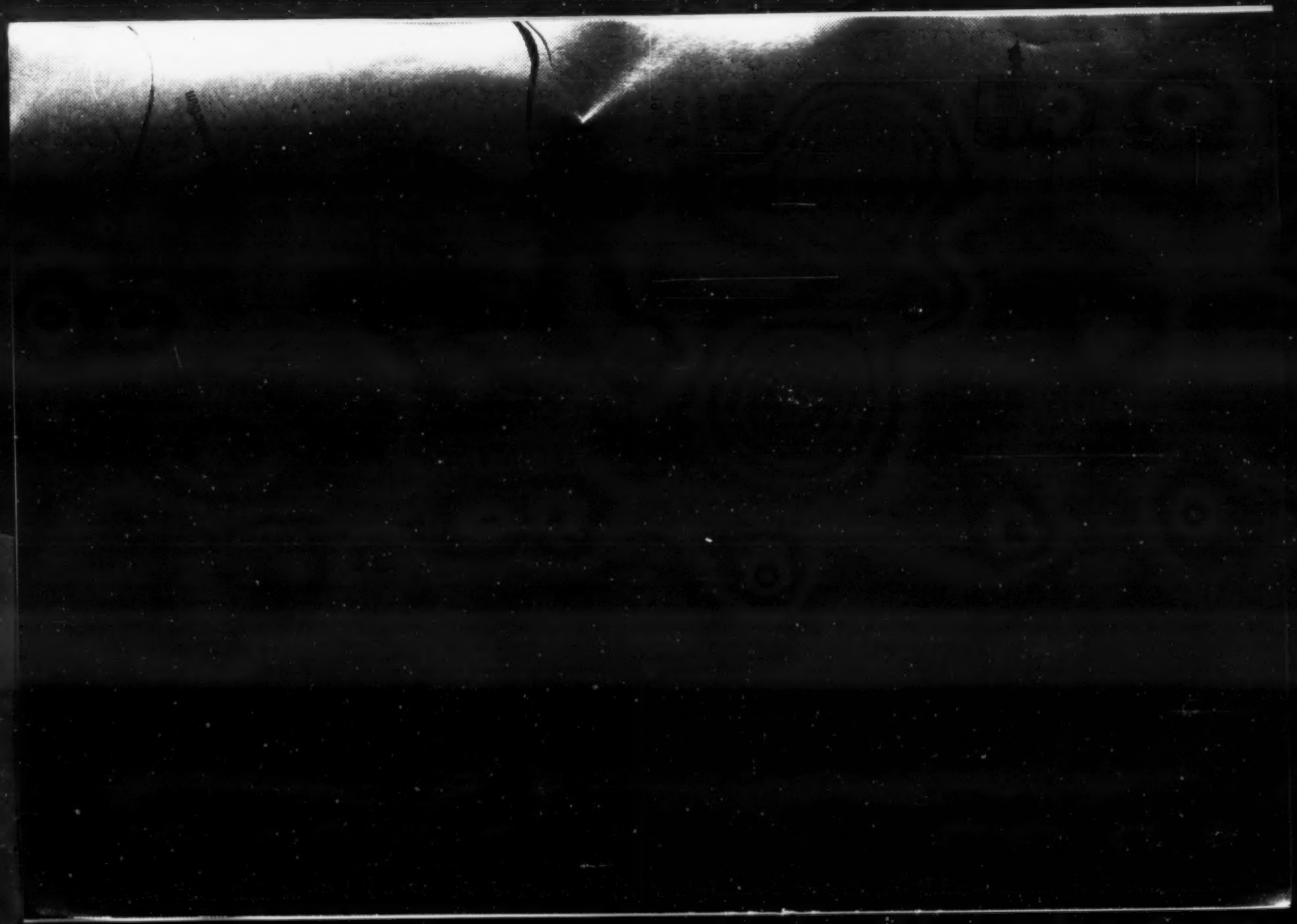
We, in manufacturing, uphold Sola's policy of conservative design by building ballasts "over spec." By using highly-trained people and careful quality control we can hold our rejects down to practically zero . . . and thus actually boost our net output.

This extra effort on our part means you can count on Sola Transformers to deliver maximum performance consistently over a long period of time. The best way to prove my point is to test a Sola ballast yourself. When you do, I'm sure you'll agree with me that the best way to insure excellent performance of your lighting system is to specify Sola.

Write for your copy of Bulletin 3E-MY-306

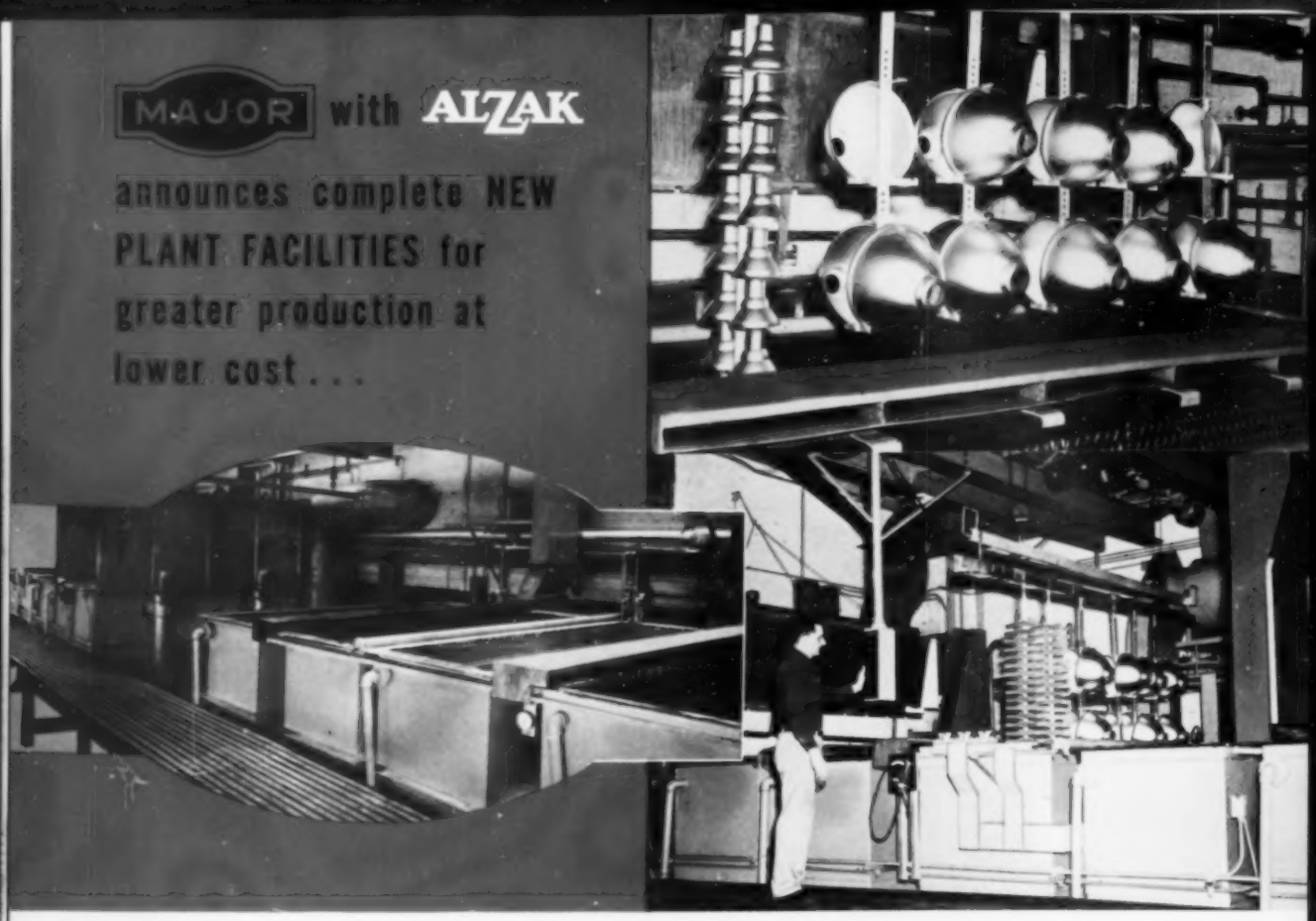
Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

SOLA

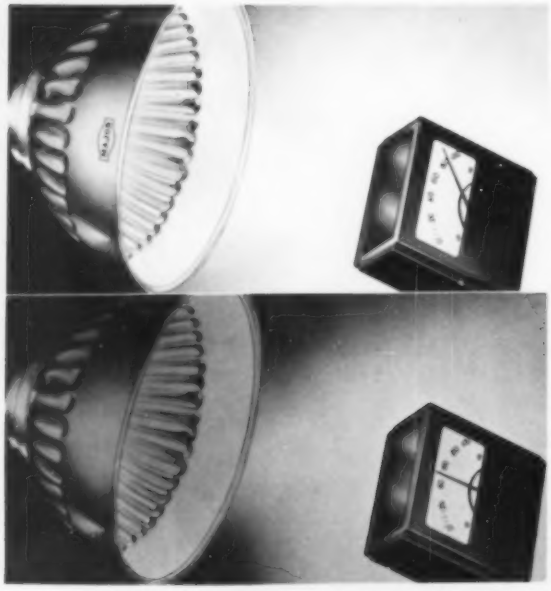


MAJOR with ALZAK

announces complete NEW PLANT FACILITIES for greater production at lower cost . . .



Here's why ALZAK* gives you the BRIGHT LOOK in lighting that lasts. Results of tests after years of use.



WITH ALZAK REFLECTORS

When ALZAK process reflector surfaces are employed in any lighting situation a greater lasting power of reflection results. Major treats the brightened aluminum surface to a series of special processes that produce an unsurpassed durable reflector for both indoor and outdoor use, that outlasts any known processes. Here the reflectometer shows an exceptionally high reading of superior quality reflection, even after 5 years use.

WITHOUT ALZAK REFLECTORS

This reflector does not show the lasting reflective power or quality of the ALZAK process. The result, as shown on the reflectometer, is inferior reflection. Although starting out together with equal reflective brilliance this material shows definite loss of lustre whereas ALZAK process reflectors maintained their reflective powers even after 5 years of use.

Major Equipment Co. manufactures ALZAK reflectors for many uses such as: Street, highway and traffic lighting; Stage lighting; Hospital and dental lighting; Outdoor flood lighting, School, stage and office lighting; Photographic lighting.

* A proprietary term of the Aluminum Company of America.

new technique

CUTS COSTS IN RELIGHTING

SCHENECTADY UTILIZES OLD CONCRETE POLES BY ADDING NEW P & K ALUMINUM CONVERSION UNIT

Problem: how to relight at a minimum of cost, both in units and erection. Solved by P & K engineers! Schenectady, New York utilized their old standing concrete poles by fastening tapered aluminum shafts with graceful six-foot arms and incandescent luminaires. Thus, in one easy-to-install unit they provided the lighting intensity they wanted at a minimum cost. As for maintenance problems, there are none. P & K all-aluminum standards never need painting or other costly maintenance. They maintain their good looks and offer unsurpassed resistance to weather. For your next lighting installation, consult P & K first. For more help, send for Catalogs ALS and L-2 describing standards and lighting units for all applications.

SCHENECTADY PREFERRED P & K BRIDGE CONVERSION UNITS

Of course, since P & K offers a wide range of styles in standards, both davit and the conventional type, Schenectady in effect customized their installation with modified standard parts. It's easy to modernize existing obsolete street lighting installations the P & K way.

P&K **PFAFF & KENDALL**

84 FOUNDRY ST., NEWARK 5, NEW JERSEY

ALL PLASTIC EXTRUSIONS ARE NOT THE SAME

*there's a difference**

*** That Difference is the Extra Features you can expect and depend on, when you buy or specify extrusions by ROTUBA**

1 Color. The New Azure-White. Visually pleasant and complimentary. Acclaimed by all who saw it at the National Lighting Exposition as a welcome color improvement for the Industry.

2 Extra Wall Thickness where it counts.

3 Destaticized on **BOTH** sides.

4 Uniform Wall Thickness for Even Light Transmission.

5 As much as 20% more usable light transmitted with superior obscuration.

6 Radius for greater strength.

7 No ribbing. No matte finish. Smooth, lustrous surface is easier to clean, stays cleaner much longer.

Here's Your ✓ Check-List

Do Your Present Extruded Shapes Have All These Important *Extra* Values?

1 _____ 4 _____
2 _____ 5 _____
3 _____ 6 _____
7 _____

Die Shape #127 Shown Here Is Actual Size.

IT'S NO SECRET. *THESE ARE THE FACTS.*

We do not use standard Polystyrene, but only premium-priced materials that have the greatest degree of heat resistance and color permanence.

Send for a sample of our Die Shape #127 today.

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ROTUBA EXTRUDERS, INC.
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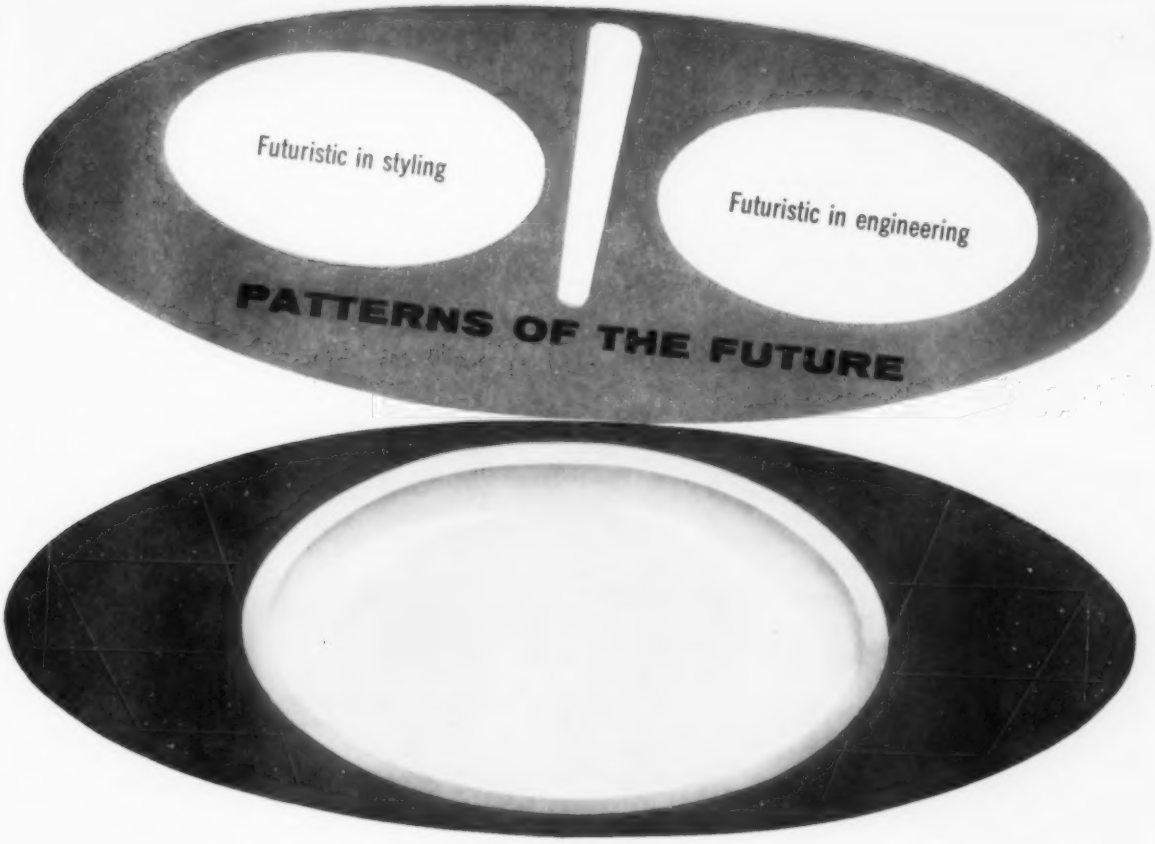
Makers of QUALITY PLASTIC EXTRUSIONS FOR INDUSTRY

Affiliated with WALJOHN PLASTICS, INC. — Flexible Plastic Extrusions and MARIDON MFG. CORP. — Injection Molded Plastics



. . . heralded by
these handsome "large area," recessed, 4-foot in diameter, circular Visionaires: the SP3840 series. Besides widening the architectural-designer's range of dramatic concepts in interior designs, the SP3840 is ideal either as a contrast fixture or the dominant shape in the ceiling theme. Matte-finish translucent white Plexiglas affords distinctive illumination: unusual low brightness, minimum glare and greater visual comfort. Diffusers are concave for added strength and structural stability. Fixture-body is square for easy installation. Loosening of only 4 screws permits fully framed diffuser to be lowered on concealed slotted hinges for relamping without removal. Bonderite treated against corrosion and finished in high reflectance, all white baked enamel. Also available 24" and 36" in diameter. Write for bulletin D-49.

SUNBEAM LIGHTING COMPANY

SUNBEAM visionaire

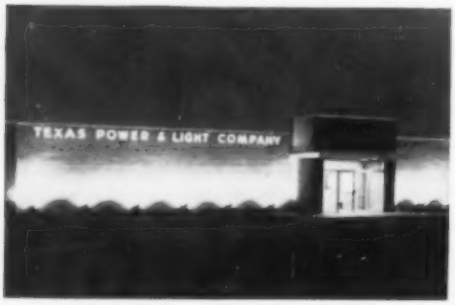
Complete Manufacturing Facilities in Gary and Los Angeles

777 E. 14th Pl.
Los Angeles 21, Calif.

3840 Georgia St.
Gary, Indiana

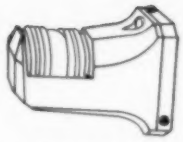
Revere Outdoor Lighting Report

Lighting a building exterior



The Problem: To highlight a new building through the use of dramatic lighting of the building exterior. Fixtures must be attached to the building itself.

The Answer: Ten Revere No. 3151 Underneath Floodlights were installed to provide a source of uniform, glare-free light for the exterior walls of the building. Underneath Floodlights were chosen because they are unobtrusive and because they project a wide, flat pattern of light. Fixtures are completely weather-tight and insect-proof.



No. 3151 Underneath Floodlight

Lighting a shopping center parking lot

The Problem: To illuminate the large parking lot of a modern shopping center, providing a safe, attractive place for shoppers to leave their automobiles.

The Answer: Revere Ultra-Lites, multiple mercury luminaires, were installed throughout the parking area. The square light patterns were overlapped to achieve a uniform, glare-free light level. The use of Ultra-Lites cut pole requirements by more than 50% because of much higher utilization of light per fixture.

No. 5442 Ultra-Lite

Lighting a residential street

The Problem: To light a quiet neighborhood street with moderate-level illumination concentrated on the street with lesser amount on the sidewalk.

The Answer: Revere Urban-Lite luminaires were installed on one side of the street. Projection pattern of units made possible the even lighting of street and additional light on sidewalk with minimum stray light entering adjacent homes. Urban-Lite is an economical way to utilize smaller, highly efficient mercury lamps.

No. 2100 Series Urban-Lite

Write for Revere's complete catalog of outdoor lighting equipment

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 31, Illinois

Available in Canada thru Curtis Lighting, Ltd., Leaside, Toronto, Ontario

Announcing . . .

a new hinged design*
in ceiling
pan fixtures by

PERFECLITE

Perfeclite now offers a new **hammer lock** design in incandescent ceiling pan lighting fixtures. No other ceiling pan fixture on the market today has all these engineering features:

- Globe opens on **hinge** for quick easy cleaning and relamping.
- Unique **safety locking fitter** holds globe in place without bothersome screws, unsightly extensions or trick springs. Globe is secured with lugs by simple twist of the wrist.
- Lip of globe is completely protected against breakage by a **steel protector ring.**
- Provides **ceiling illumination** as well as **evenly distributed floor lighting.**
- Minimum amount of metal, maximum amount of glass results in **highest light efficiency.**

Here is a unique ceiling pan fixture design for either commercial or residential installation. For further information send for The Perfeclite Data Sheet 56-C today.

Perfeclite's new **hammer lock** fixture is available in the following sizes:

Model	Glass Diameter	Wattage
HH-9	8"	2- 40 W
HH-11	10"	2- 60 W
HH-13	12"	2- 75 W
HH-15	14"	2-100 W
HH-17	16"	3-100 W

Send for new Perfeclite Catalog 956 giving full information on our entire line of Commercial Incandescent Fixtures and Exit Units.

Fixtures are Underwriters Laboratories, Inc. approved.

*Patent pending

THE PERFECLITE COMPANY

1457 East 40th Street • Cleveland 3, Ohio

☐ Please send me The Perfeclite Data Sheet 56-C.
☐ Please send me the new Perfeclite Catalog 956.

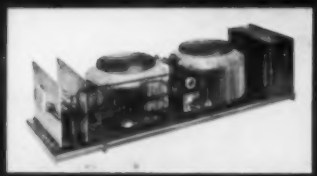
Name.....

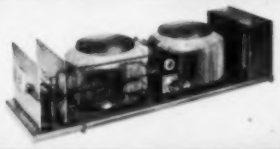
Address.....

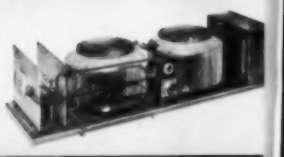
City.....State.....

PERFECLITE PRODUCTS
THE MARK OF LIGHTING SERVICE

PRESENTING . . .







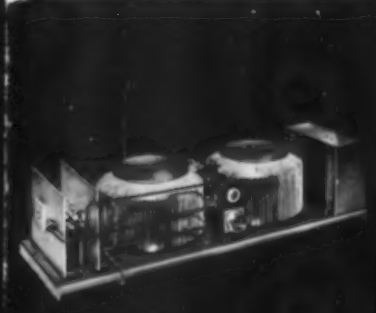
THE ULTIMATE IN MAGNETIC AMPLIFIER DIMMERS

FOR LIGHTING LOADS UP TO 10,000 WATTS

AND NOW

. . . a radically new concept in Magnetic Amplifier design, *specifically* developed by LUMITRON for TV and Stage Lighting Control. Featuring totally inert components, the modularly designed LUMITRON Magnetic Amplifier has a unique universal load ratio. Comparison *proves* that this new Magnetic Amplifier provides nearly *twice* the load capacity of competitive Dimmers. Comparison also proves that the LUMITRON Dimmer offers the multiple advantages of a Magnetic Amplifier in a more compact, *infinitely superior* unit which *costs* less, *weighs* less and takes up much less space. *Guaranteed for three years.*

COMPARE . . . and you will find the dependable, economical LUMITRON Magnetic Amplifier to be the only *logical* choice for low cost, high quality Lighting Control.



SPECIFICATIONS	LUMITRON Magnetic Amplifier	MAGNETIC AMPLIFIER "A"	MAGNETIC AMPLIFIER "B"
POWER CAPACITY	10,000 Watts	6300 Watts	6300 Watts
LOAD RANGE	1-10,000 Watts	210-6300 Watts	210-6300 Watts
SIZE	1.4 cubic feet	2.7 cubic feet	2.1 cubic feet
WEIGHT	146 pounds*	158 pounds*	156 pounds*
LINE VOLTAGE REGULATION	±2% for ±15% line voltage	none	none
OUTPUT CURVE CONTROL	From linear Light to linear voltage exactly as specified	slight arbitrary adjustment	slight arbitrary adjustment
PRICE	competitive*	competitive*	competitive*

**Note that the price and weight of the LUMITRON 10,000 Watt Dimmer is compared with the other 2 units of 6300 Watt capacity. It is, therefore, less expensive and lighter.*

Because of the size, weight and rugged construction of the LUMITRON Dimmer, a system utilizing it can be supplied which will "troupe" satisfactorily.

C. L. Schuler, Inventor
PATENTS PENDING

CREATIVE ENGINEERING FOR THE LIVING THEATRE BY . . .

LUMITRON *DIVISION*

METROPOLITAN ELECTRIC MANUFACTURING CO.

2248 STEINWAY AVENUE • LONG ISLAND CITY 5, N. Y. • ASTORIA 8-3200

LIGHTING CONTROL SINCE 1892
METROPOLITAN

Sylvania Mohawk Fixtures get permanent library duty in new College of Education Building, University of Tennessee, Knoxville, Tenn. Architects and engineers on job: Barber & McMurry, Knoxville.

Sylvania Mohawk Fixtures . . .

the modern approach to surface-mounted lighting

No matter how low the ceiling—you can always find room for quality lighting with Sylvania's 3¾"-deep Mohawk. In long, lean rectangles or shallow square designs, these new fixtures have a clean and classic look about them that *is* tomorrow in good lighting.

In providing more than two dozen different lighting design combinations, with only a few standardized components, the Mohawk Series is one of the most complete fixture lines of its type today. It gives you a custom approach to lighting . . . choice of 2 standard widths, 2-, 4-, or 8-foot lengths, and 5 different types of shielding.

Ask your local Sylvania Fixture Specialist for his demonstration of the Mohawk's many short- and long-term cost-saving features. And write direct for FREE booklet V-100 with complete specification data.

SYLVANIA ELECTRIC PRODUCTS INC.
Dept. **E30**, Lighting Division—Fixtures
One 48th Street, Wheeling, W. Va.

Metal-louvered Mohawks (one-foot width) provide clean architectural design, with shielding needed for high footcandle levels, in new university classrooms.

Dished contour plastic shielding on Mohawk provides attractive lighting design for corridors. Installation by Broadway Electric Service, Knoxville.

SYLVANIA

Fluorescent Lighting Fixtures and Systems

Best fixture value in every price range

LIGHTING • TELEVISION • RADIO • ELECTRONICS • PHOTOGRAPHY • ATOMIC ENERGY • CHEMISTRY-METALLURGY

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EXTENDS YOU

A HEARTY WELCOME

TO

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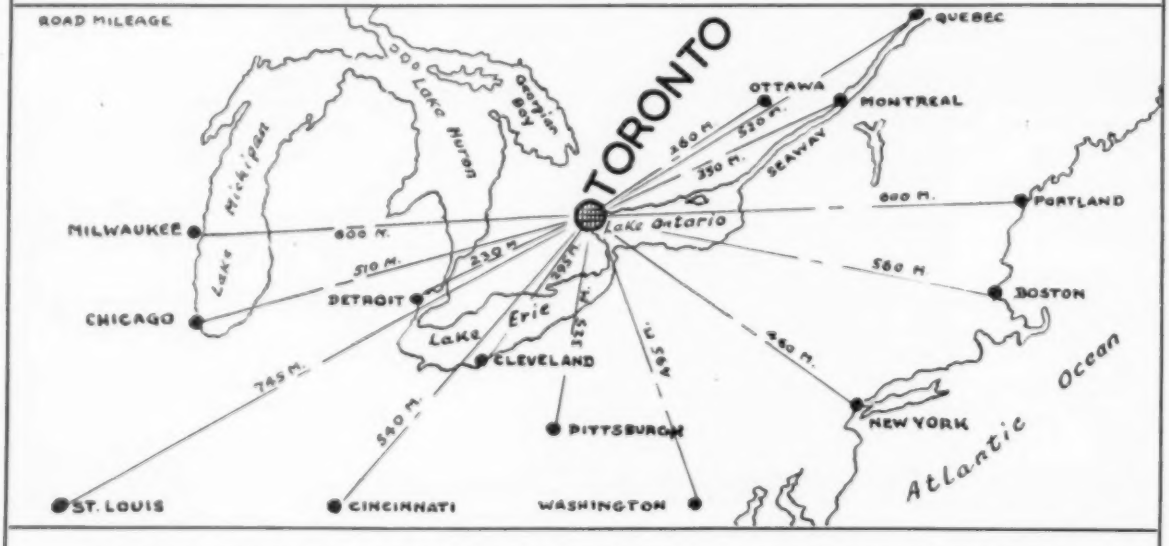
1958 National Technical Conference

Illuminating Engineering Society

Royal York Hotel — August 17-22

- Presentation of the latest in the science of illumination
- Full technical program
- Entertainment, tours, golf and many surprises to make this conference a glorious event.



PLAN YOUR VACATION THEN — VISIT CANADA

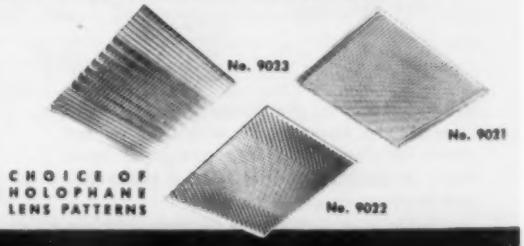
® Registered by Holophane Company, Inc.

AND IT BRINGS YOU AMERICA'S LATEST FAMILY OF TROFFERS — BY ALL-BRITE

Designed in superb styling . . . a wonderful wedding of All-Brite's new recessed line with Holophane lenses. Write for catalogs, details.

Famous for manufacture of fine lighting fixtures, All-Brite is now a proud Holophane lens-lighting distributor.

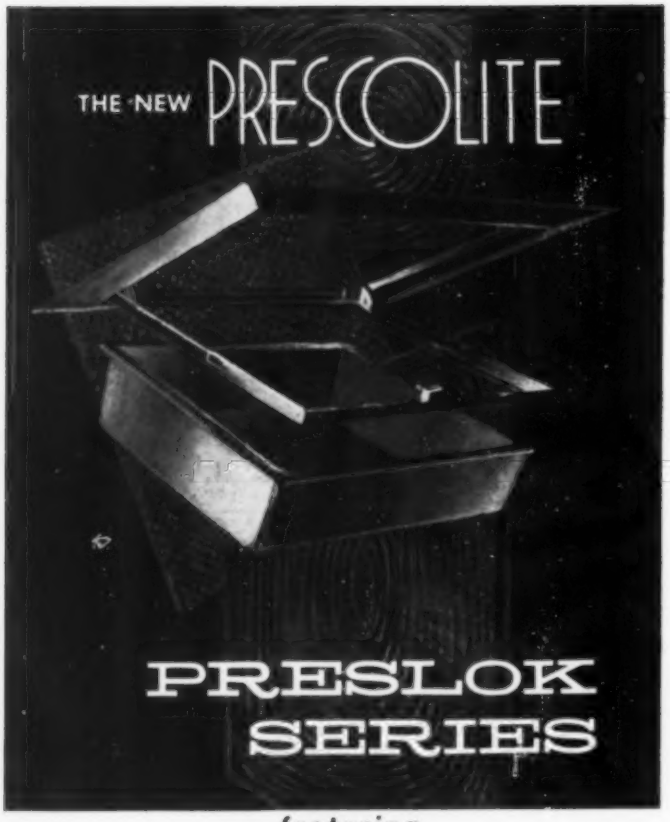
All-Brite
LIGHT OF THE WEST



FLUORESCENT FIXTURES OF CALIFORNIA

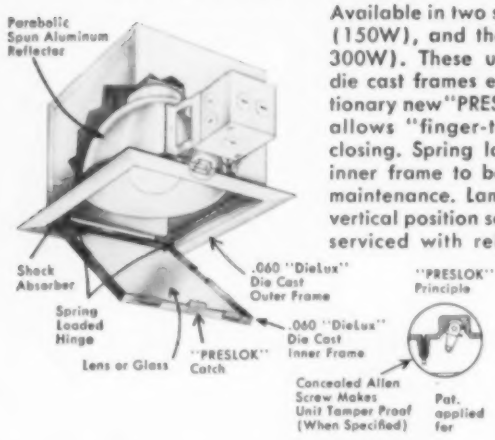
352 SHAW ROAD
SOUTH SAN FRANCISCO, CALIF.

PLANTS ALSO IN LOS ANGELES, PORTLAND, OREGON, AND VANCOUVER, B. C. CANADA



featuring

A New Conception in Hinged Frames for Recessed Lighting Fixtures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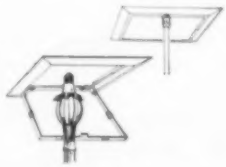

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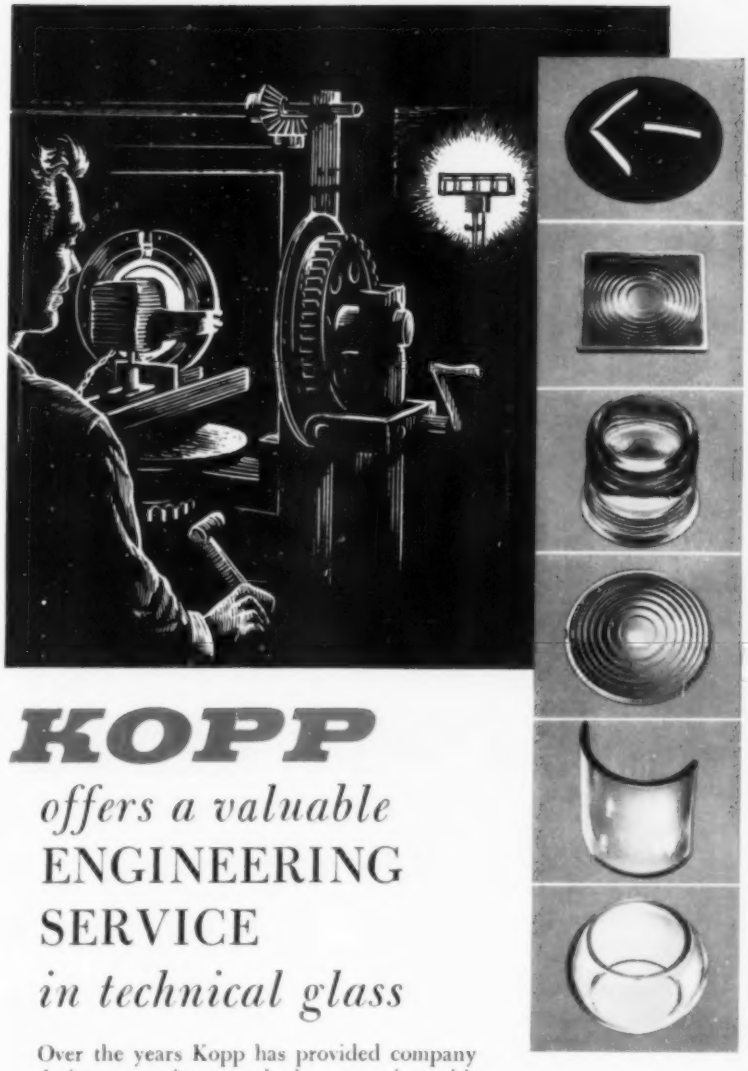

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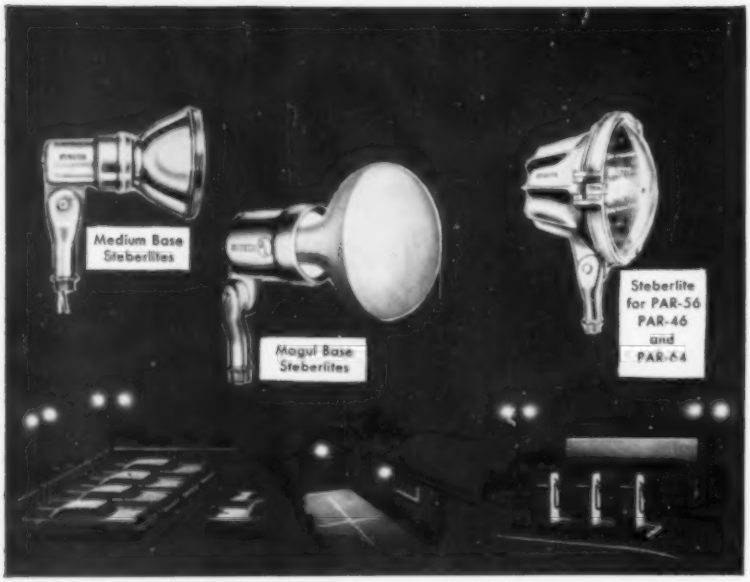

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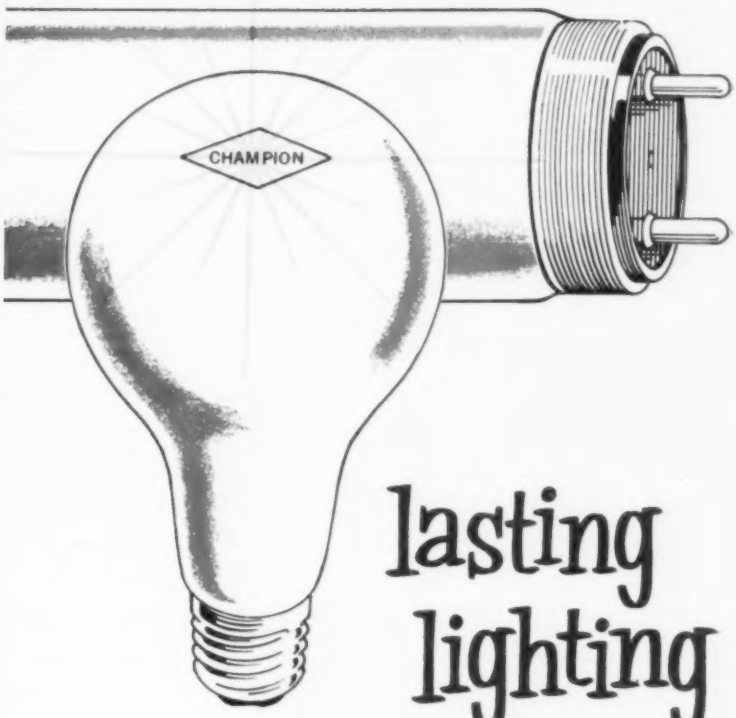

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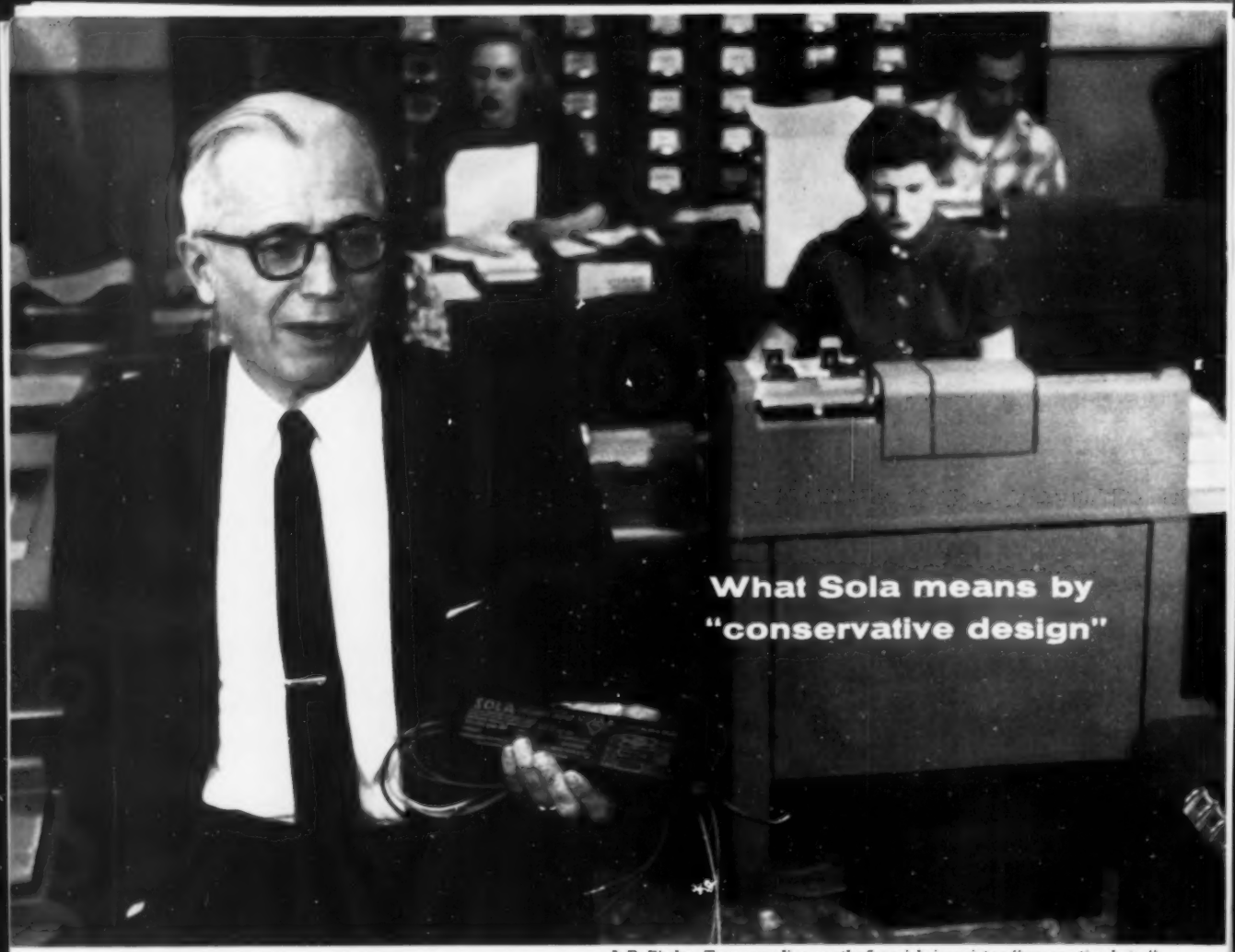

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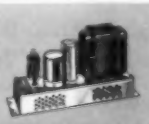
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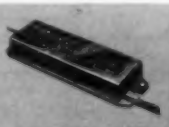
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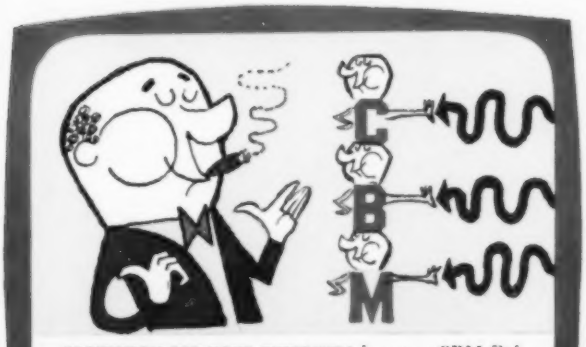

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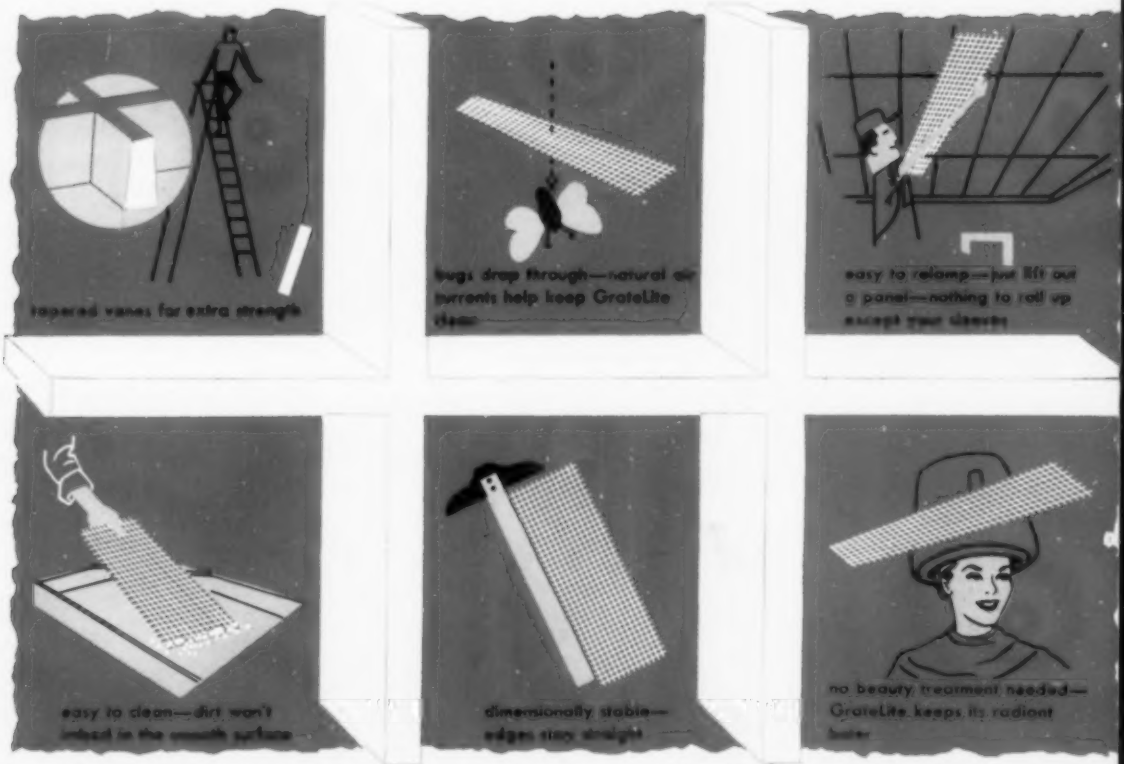
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